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THE PHILADELPHIA CITY HALL CLOCK.

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For many centuries the pendulum has been recognized as the fundamental element in a mechanism for indicating and recording time. The characteristic of the pendulum which gives it its supreme place in clock mechanism is the fact that a pendulum of a given length, at the same point and elevation, will oscillate in equal periods. This is the theoretical statement of the fundamental law. In order that a given pendulum should follow this law, it must be relieved of two disturbing influences; namely, friction and external influences retarding or varying its original motion. The friction is from two sources: between the parts of the mechanism and between the pendulum and the surrounding air. This friction not only varies the oscillations of the pendulum from their normalcy, but ultimately brings the

pendulum to rest. Unaffected by the disturbing causes which I have mentioned, a pendulum would continue to move forever when once put in motion. The sole object of applying springs or weights to a clock mechanism is to supply the exact amount of energy lost in friction. As it is impossible to make a pendulum to operate under ideal conditions, springs or weights must be used; but to reach as near perfection as possible, the entire mechanism must be reduced to its simplest form. A simple pendulum has mechanical friction at only one point and that is the point of suspension. This is reduced to a minimum by avoiding a bearing in which one part rubs against another, using instead a very thin suspension spring, wherein the only friction is produced by the flexure of the spring as the pendulum oscillates. The air friction, not being avoidable, is made as uniform as possible by enclosing the pendulum in an air-tight casing. A simple pendulum, however, would not indicate or record time and hence it is necessary to add indicating devices called hands, which move in accordance with the oscillations of the pendulum. The whole mechanism, therefore, consists of a pendulum, an application of power to balance friction, and recording and indicating hands. The power mechanism acts upon the pendulum to keep it in motion, and the pendulum, through a detent, reacts upon the power mechanism, so as to use the energy in uniform and equally divided amounts at exact intervals, namely, at each swing of the pendulum. Even allowing for the disturbing elements of friction and the external interferences, the pendulum would still be theoretical, since I have considered a pendulum which is always of a given length. Unfortunately, under natural conditions, a pendulum made of a single material will change its length at each variation of temperature, and means are, therefore, employed to counteract this variation by offsetting the expansion of one material against that of another, so as to, as nearly as may be, keep the pendulum at a constant length. No combination of materials, however, will exactly suffice, and, therefore, there is always under ordinary conditions a third disturbing element, namely, temperature, and this has more

influence proportionately on the variations of the clock than friction, since the friction, both mechanical and of the air, is constant, while temperature is variable within great ranges.

From the requirements and the natural difficulties under which they operate, accurate clocks must be of the finest workmanship, designed upon the highest principles in the horological art and removed from all disturbing influences as far as is possible. So far as the mechanism is concerned, what is called an astronomical clock comes the nearest to meeting the requirements. An astronomical clock is the simplest of all clocks, employing no additional mechanisms for striking the hours, etc. It is unnecessary for my purpose to go into the details of their construction, it being sufficient to say that there are as few bearings as possible, all bearings are jewelled, the gearing is the most perfect, the pendulum hung with the thinest spring which will sustain its weight; the pendulum is compensated, so far as possible, for variations in temperature and is protected from air movements and, so far as is possible, from jarring from external sources.

What I have previously written is to note, briefly, the principles and necessary conditions under which an accurate timepiece must work. Clocks at first were of the ordinary size and for use within buildings. Finally equal use was found for public timepieces by which the poor as well as the rich might benefit; in other words, a public convenience. That they might be serviceable at great distances, they were necessarily elevated and for the same reason were provided with dials of great magnitude as compared with house clocks, and the mechanism and power applied were proportionately increased. Aside from the increase of friction, there was the increased vibration, owing to the elevation; the external variations of temperature, which not only varied the length of the pendulum, but affected all lubricants which are necessary in mechanism. I have said that an accurate clock must have as little external mechanism as possible added to it. A tower clock, since its hands are exposed to wind and weather, requires at all times considerable energy to operate them, but

owing to changes of wind, and with snow and sleet, *varying* power to operate them. It follows that a tower clock built upon the lines of an ordinary enclosed clock of practical dimensions cannot be extremely accurate, while, being for public use, it should be the most accurate of all clocks.

The tower of the City Hall in Philadelphia was designed for a tower clock, but, owing to the extreme height of the tower and the size of the dial face, presented problems not before encountered in the installation of a tower clock.

The total height of the tower is 547½ feet from the ground, and the centers of the dials, 362 feet above the pavement. The diameters of the dial openings are 25 feet, including the rim. The height is so great that the dials are often obscured by clouds, and during the erection of the clock the ironwork was frequently wet with deposited moisture, while the pedestrians below were in a dry atmosphere. When only moderate breezes blow in the street, a gale is experienced at the clock dials. The tower up to the level of the clock dials is built of brick faced with marble, but the upper 200 feet is constructed of iron electro-galvanized with aluminum. The tower, of course, is unsupported above the roof of the main building. The top of the tower has a small diurnal motion accompanying that of the sun and owing to the expansion of that portion of the tower upon which the sunshine falls. All of these conditions made the installation of a tower clock of such prominence (which of course must be accurate) practically impossible, if built as a primary clock.

Mr. John S. Stevens, Chairman of Clock Committee and a member of this Institute, in view of the future installation of a clock in the tower, made a special study of tower clock mechanisms and had visited all the most prominent tower clocks in the world. From his investigations, he foresaw the practical difficulties. At this juncture, Mr. Stevens consulted me, as I had previously designed and constructed the largest clock in the world at Minneapolis, Minn., the dials being 22 feet 8 inches in diameter.

After examination of the building and tower, I under-

took the designing and erection of a time-indicating device suitable to the location and conditions, and the clock at this writing has been in operation two years. The departure from the older method is radical and will be understood by the following text accompanied by illustrations. The conditions under which such a clock must operate and the magnitude of the dials and of the hands is such that their designing becomes an engineering problem and not a horological problem. But in order to have accurate time, there must be an accurate timepiece, the construction of which belongs to the horological art. How I have combined the two will be seen by the description. In brief, the *real* clock, the accurate timepiece, serves only to put in motion and to control the tower mechanism, and there is, therefore, really no *clock* at all at the great height of the dials. The dial mechanism is operated by compressed air. The whole is based on the fundamental principle of all modern mechanisms, namely, the governing and directing of great forces by comparatively feeble ones.

Fig. 1 is a view of the City Hall in Philadelphia taken from the roof of the tall office building across the street. The form of the building is a quadrangle, with a court in the center, which covers four city blocks, two streets running through the building, one north and south, one east and west. The tower rises from the north side of the quadrangle at such a point as to be supported on east and west by the building itself. The clock dials are 362½ feet from the ground at their centers, the tower rising nearly 200 feet above this point. The astronomical clock is placed in the lowest room of the tower, which is just above the roof of the building itself. Air pipes lead from this point over 200 feet to the dial room above. These pipes also lead downward into the basement of the building, where there are air compressors operated by water for furnishing the power in emergencies, the main air compressor being operated by electricity and located in the dial room.

As the astronomical clock is the heart of the whole apparatus, my description will begin with the astronomi-

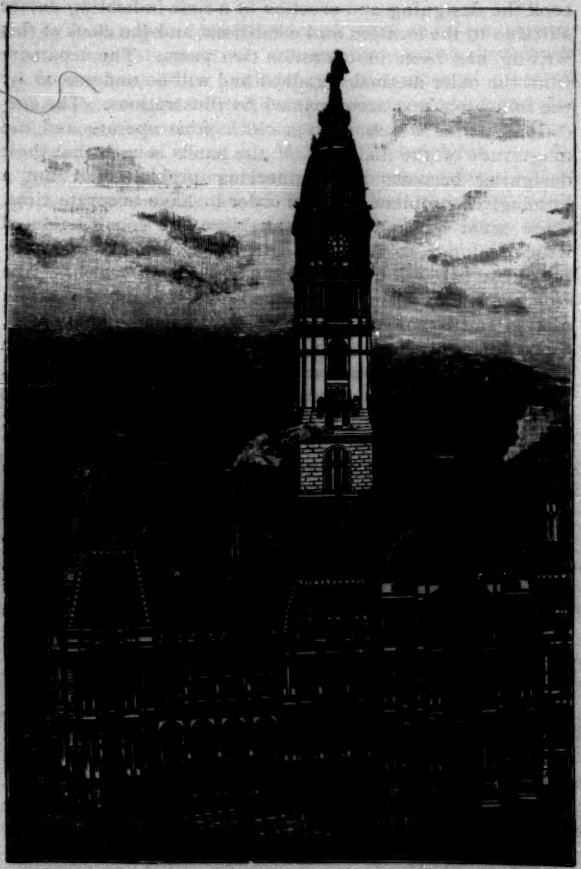

FIG. 1.—City Hall, Philadelphia.

cal clock and its immediate accessories. The best location for this clock would have been, of course, on the level of the street or below, but owing to the peculiar construction of the building, such a location could not be secured. It was, therefore, determined to put the astronomical clock in the next best position.

FIG. 2.—Partial view of clock room.

In the lowest room of the tower, which is on the seventh floor of the building, the walls are 13 feet thick. One corner of this room was selected and iron girders were let into the walls so as to cross the corner, and these girders furnished the foundation for the clock room, being entirely independent of the floor of the room, so that they would not take up any jar or vibration which the floor might have,

being as rigid and solid as the tower itself. Using these girders as a foundation, there was built a room of iron and copper, the foundation work being covered with marble, and the inside surface of the tower walls which came within the clock room were faced with glazed tiles. This clock room was made as perfectly air- and dust-tight as possible, by having all the glazings, as well as all the door openings, fitted with felt. This prevents the accumulation of dust, which would be detrimental to the working of the astronomical clock. The room is so tight that after six months' use not a particle of dust could be found to have settled on the clock casings in the room. A general view of the front of this room is shown in *Fig. 2*. *Fig. 3* is a cut of the astronomical clock as it appears standing alone. The clock is mounted on an iron pedestal weighing over 500 pounds. This pedestal has three adjusting screws, as will be seen, so that the clock may be brought to a perfect level at any time. The pendulum is enclosed in the pedestal. The weight also falls within the pedestal, but in a separate compartment from that of the pendulum, the object being that the weight when it falls, necessarily passing the pendulum, will not thereby influence the air friction, the air friction remaining constant at whatever position the weight may be. The dial mechanism of the astronomical clock is above the iron pedestal and enclosed in a glazed casing which may be removed when necessary. This is set upon felt strips, so as to provide against dust, as in the case of the room itself. The casing is not removed to wind the clock, but a plug is removed from the glass in front and by means of a long key the clock is wound through the hole once each month, the plug being replaced after each winding. The clock, therefore, has a double protection against dust, that is, the dust-proof clock room and the dust-proof case.

As is common with astronomical clocks, the dial has three circles, the minute circle above the center, the hour circle on the circumference of the dial and the twelve-hour circle beneath the center.

Again referring to *Fig. 2*, there appear to be two astronomical clocks. That is not the case. The clock to the

FIG. 3.—Astronomical clock.

left, marked *B*, is called an auxiliary clock. It is mounted in exactly the same way as the astronomical clock, but is of much cheaper mechanism and is used only in emergencies when it would be necessary to oil or otherwise adjust the astronomical clock. In *Fig. 3* small pipes will be seen passing up through the pedestal of the clock at the rear, and are seen on either side of the pendulum. These pipes con-

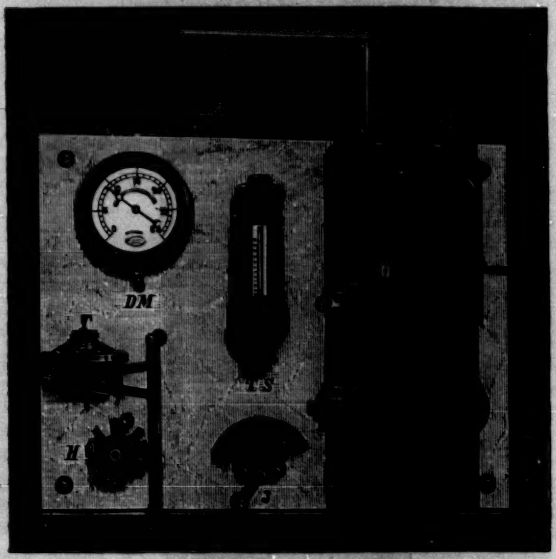

FIG. 4.—Thermostat, air switches, electric switch, telegraphic sounder, etc.

vey the compressed air to and from the clock mechanism. The function of the astronomical clock is to control compressed air, which moves the hands of the dials 200 feet above. On the rear wall of the clock room there is placed some accessory apparatus, which is shown in *Fig. 4*. *D M* is a pressure gauge which indicates the pressure used, shown in the cut to be about 9 pounds, although the exact pressure is

immaterial. At the left is a telephone by which any desired person may be called up from the clock room, and communication may be had if necessary with the local observatory, but the time is really governed by the electrical relay *Z*, which is placed above the telephone. This electric relay is connected by direct wire with the U. S. Naval Observatory in Washington, and each day, just before high noon, the relay begins to repeat the second movements of the pendulum in Washington. Ten seconds before the meridian the relay rests, and the first click after the rest is exactly noon. This relay is made to sound so loud that it is not necessary to go into the clock room to hear it, and, of course, the dial of the astronomical clock may also be seen through the plate glass of the room. In this way it is not necessary for any one to enter the room oftener than once a month. The presence of the human body in the room for more than a few moments has been found to be detrimental. The room is so tight that the moisture given off by the human body, which, of course, is considerable, remains in the room and is detrimental to the delicate mechanism. For this reason admittance to the room is denied, even to the attendant, excepting once a month.

Handle *3* is a switch for the compressed air. From the position in which the pointer of the switch is shown, the astronomical clock controls the tower mechanism, but if the pointer be reversed to the left, the auxiliary clock controls the mechanism, and the reversal of this index is all that is required to change the tower mechanism from the control of the astronomical clock to that of the auxiliary clock, or *vice versa*. In the center of the marble slab which supports these accessories is seen a device marked *T S*. This is a thermostat, which also controls compressed air, and the compressed air in its turn controls the electric switch *H* through the mechanism *T*. In the room at one side is an electric radiator or heater, and the current which supplies it is controlled by the switch *H*. The thermostat has the function of supplying or shutting off this current at the proper temperature. The thermostat is set at a temperature of 75° F. As soon as the temperature of the room reaches this

point, the thermostat, through the compressed air, opens the switch *H* and, therefore, the source of heat is removed. When the temperature falls less than 1°, the thermostat, through the mechanism *T*, closes the switch *H*, and the electric radiator or heater again comes into action. This apparatus is so perfect that the temperature of the clock room never varies more than 1°. It is set at 75°, so as to be as near as possible to any summer heat which might enter the recesses of the clock room, and, therefore, is as warm in the winter as it gets in summer, and remains during the year at the constant temperature of 75°. This eliminates from the problem the question of temperature, which is one which has been found most troublesome in securing accurate time mechanism. This is the only astronomical clock in the world which operates under such perfect conditions.

It will be interesting to know how the astronomical clock, without interfering with its delicacy and accuracy, can operate four sets of hands, each weighing 500 pounds. I will refer to *Fig. 5*, which is a more or less diagrammatic and sectional view of the controlling mechanism. *R* is the inlet for compressed air, which is supplied by one of the vertical pipes in the clock pedestal, as before stated. This air is supplied to two portions of this mechanism, one portion to a valve marked *V* and the other to the vertical passage where there is a threaded pin valve *X*. The air which passes through this pin valve underneath the flexible diaphragm *m* passes upward through the small tube *u*, which is continued into the clock mechanism and terminates at *n*. On the second hand arbor of the clock, that is, the arbor above the center, is placed the cam *g*. The lever *H* is fulcrumed as shown and lies across the opening of the pipe *n*, so as to close this pipe when it rests upon it. During the revolution of the second hand arbor, the cam *g* one-half of the time will raise the lever *H* from the pipe *n* and leave it open. During the other half, it will be closed. The opening in the pipe *n* is larger than the opening through the pin valve *X* to the clock chamber *m*. It follows, therefore, that when the lever is removed from *n* by the cam *g*, the chamber *m* will collapse from lack of pressure. When

n is closed, the chamber *m* will expand, since the pressure passing through *X* will accumulate. These actions take place each minute, the chamber *m* being alternately repleted and depleted of air. The diaphragm itself is not much larger than is shown in the cut. The movements of this diaphragm inward and outward operate the lever *b* against the spring *W*. Connected with this lever is a toggle which operates the valve *V*. It is unnecessary to give a minute description of this movement. When the cham-

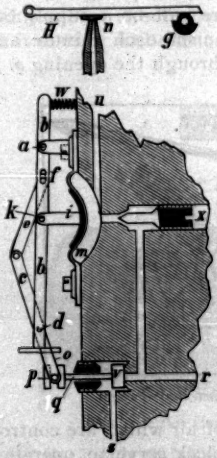

FIG. 5.—Controlling mechanism.

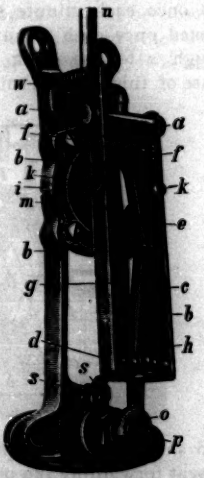

FIG. 6.—Controlling mechanism.

ber *m* is full of compressed air, the valve *V* will be in the position shown in the cut and no air can pass by it. When, however, the chamber *m* is depleted, the spring *W* forces the lever *b* back and through the toggle reverses the valve *V* so that it closes the outlet *q* for the air, but opens the air passage at *V*, the valve itself resting to the left, instead of to the right. There is now freedom for the air to pass from *r* to *s*. *s* is the passage which leads to the air pipe which passes up the tower to the dial mechanism. All the pas-

sages and mechanisms are about the size shown in diagrammatic view *Fig. 5*. The real mechanism, however, is best seen in *Fig. 6*.

It will readily be perceived that when air is supplied through *Z* it may press upon any piston, diaphragm or any like device which may be in the dial room, and this device may have sufficient power through the proper mechanism to operate the clock hands. As the cam (*Fig. 5*) is upon the second hand arbor, it is evident that air will be supplied once each minute, and as the diaphragm *m* will be depleted once each minute, there will be a supply of air through *s* to the clock mechanism each minute and a release of this air each minute through the opening *q*.

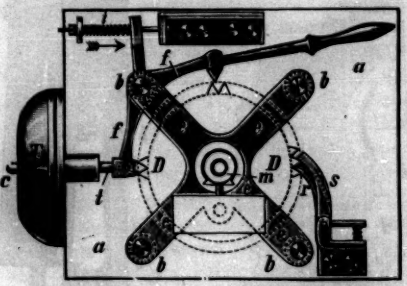

FIG. 7.—Minute mechanism in dial room.

To show how the impulses of air which are controlled and sent forward by the master clock serve to operate the dial mechanism in the tower above, we will refer to *Fig. 7*, which is a more or less diagrammatic illustration of the minute mechanism of the tower clock. The view is taken from above. *T* is a metallic chamber, concave and fitted on the inner side with a flexible woven air-tight diaphragm. The air from the master clock below sending forth impulses enters at the point *c*. The pressure of the air moves the piston having the rod *t*, and this rod *t* is fastened by a link to the anchor *f-f*, which swings in roller bearings at *b*. Studs *b-b-b-b* support the cross *e-e-e-e* which forms the

upper bearing of the shaft *m*. This shaft is prolonged upwards as seen in *Fig. 8*. Upon this shaft is a tooth wheel *D-D* having thirty teeth in the circumference. The relation of the anchor points to these teeth is such that when the anchor is pressed forward by the piston rod *t*, it forces the wheel *D* forward one-half tooth and at the same time raises the anchor point *t* from contact. By the reverse movement of the piston *T*, the first anchor point is withdrawn and the opposite one inserted, which in like manner forces the wheel *D-D* forward one-half tooth. It will be observed that this anchor effectually locks the wheel; in other words, while it rests or while in process of movement, it is impos-

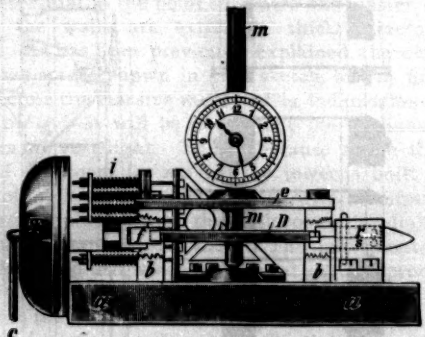

FIG. 8.—Side view of minute mechanism.

sible for the hands to fall either forward or back. In order to keep the hands in an absolutely rigid position, although there may be a movement taking place of the anchor *f-f*, pawls *r* and *s* fall into the teeth of the wheel on the opposite side from the anchor. There are two of these pawls, so that one locks at one-half of a minute and the other at the other half minute. While the piston *t* is pressed forward by the air pressure, it is pushed back by the springs *i*, of which there are seven, as shown in *Fig. 8*. The springs are divided into several, so that the breakage of a single spring will not effect the stoppage of the clock. *Fig. 8*

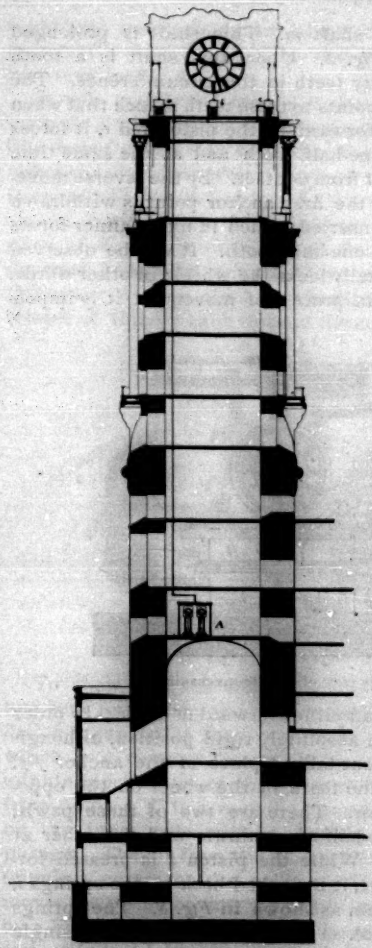

FIG. 9.—Vertical section of tower.

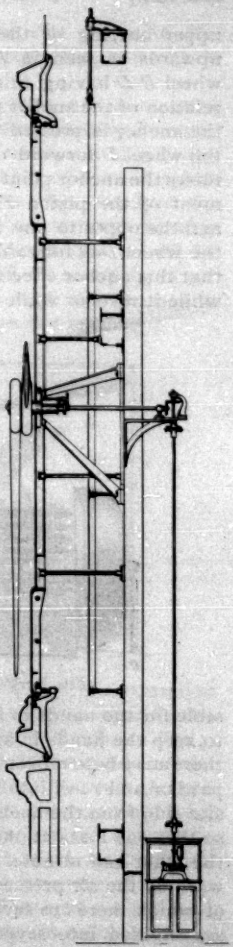

FIG. 11.—Cross-section of dial, etc.

shows the same mechanism as in *Fig. 7*, only in elevation. It will be noted that a small dial is attached to the vertical shaft *m*, so that the time may be read from this mechanism.

All four dials of the clock are not operated by a single one of these movements for two reasons: First, the impossibility of putting one center movement in the dial room, owing to the fact that an elevator passes through the center, and second, each one being independent, removes the possibility of all four dials stopping at once, owing to trouble with a single movement.

Fig. 9 shows a section of the tower from the foundation to the dial room. This shows the exact thickness of the tower walls in proportion to the interior space. It will be readily seen that at the point *A*, where the master clock is located, the walls are extremely thick, therefore substantial. As has been previously explained, the clock case *A* does not set as shown in this sketch, but is firmly attached across the massive walls and is independent of the floor. In *Fig. 9* it will be noted that the outlines of the dial room are very light. This is because above the foundation of this room, for 200 feet the tower is built of iron, instead of brick, the iron being plated with aluminum.

Fig. 10 is a plan view of the dial room, the dials themselves being marked *A*, *B*, *C*, *D*. The movements which I have described and which are placed in dust-proof cases made of oak and glazed with plate glass are shown at *E*, *F*, *G*, *H*. *I* is the elevator well. *J* is a case containing the apparatus for turning off and on the lights morning and evening (which will be described hereafter), together with the switches for the electric motors for the air compressors which are located in the same room. The outer line of *Fig. 10* is an outline of the stonework of the tower below. The dark circles are the foundations of columns which rise either side of the dials. The thin ornamental line connecting the dials at the corner is a cross-section of the ironwork of the dial room.

Fig. 11 is a cross-section of the dial, its supporting frame and of the reflecting sheet behind the dial. It shows the movement, which we have just described, in its case at the

bottom, with the vertical shaft at the side opposite the center of the dial, which shaft, by miter gears, connects with the horizontal shaft of the minute hand.

Fig. 12 is a larger, but, of course, imperfect view of the miter gearing and connections. *A* is a universal joint. *b-c* is a worm gear wheel having a key at *c*. This is for the purpose of adjusting the hands on the shaft *f*, in their relation

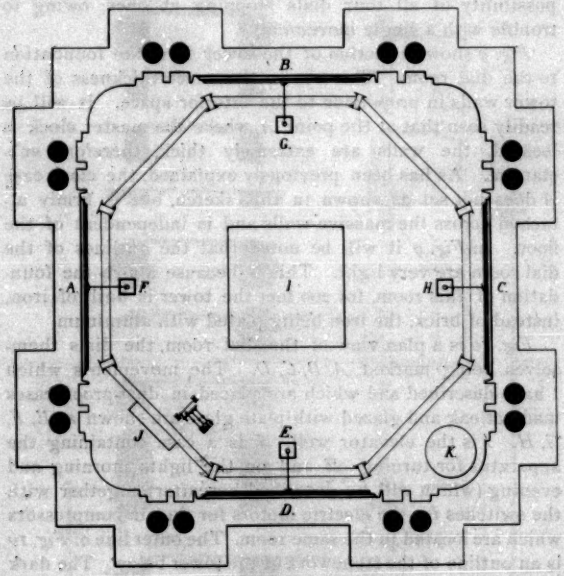

FIG. 10.—Plan view of dial room.

to the shaft *m*, so as to register them with the minute marks. This adjustment is, of course, only performed once.

The dials are the largest in the world, having a diameter of 25 feet across the centers from the extreme edges. *Fig. 13* is taken from a photograph made before the dials were

glazed. Through the openings, the city may be seen. A man stood, as shown, in one of the center circles. *Fig. 13* plainly shows the construction of the dial. It will be noted that it is sectional, having twelve separate sections bolted together, that is, for the hour sections. The minute sections are also twelve and external to the hour sections. The whole is thoroughly braced and fastened rigidly to the iron-work of the tower, which is shown by the vertical riveted sheets. The center portion of the dial is much too large for a single sheet of glass, being some 15 feet in diameter.

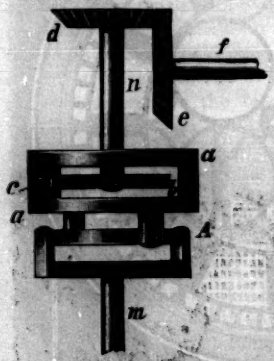

FIG. 12.—Universal joint and miter gear.

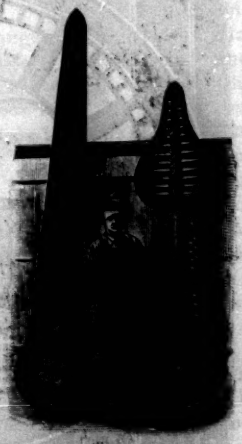

FIG. 15.—The clock hands.

It is inadvisable to section such a space radially, because the framework may be confused with the hands. By the arrangement shown, it will be seen that none of this framework is parallel with the hands at any point; consequently, cannot be confused with them; besides, the framework is comparatively light, so as not to be seen at a great distance. When seen, it is more or less ornamental. This framework is glazed with extra thick plate glass, the same being ground upon both sides. It required 2,000 feet of plate glass to

glaze these dials and sufficient glass if laid upon the ground to make a walk ten feet wide and the length of a block. The framework of the dials is made of cast iron, into which the glass is fastened with metallic clamps and bedded with elastic putty, of which it took 1,000 pounds to set the glass for four dials. The dials are perfectly water-tight. The

FIG. 13.—View of dial framework before glazing.

facing of the dials upon the outside is entirely of bronze, one-fourth of an inch thick. No iron of any sort appearing, all screws and bolts are made of bronze, which will endure, of course, always in any kind of weather. The dials are so far above the ground that during their construction the workmen were often in the clouds and the ironwork was

kept wet with the deposit from these clouds. Consequently, iron used exteriorly would be out of the question.

Fig. 14 is a sketch showing the dials from the outside. It also shows in sections the reflecting sheet which is behind the dial, the tower itself is supposed to be removed or transparent. It will be noted that there are no marks as 1, 2, 3, 4, 5, etc., in Roman numerals. Each block has the same value. All tower clocks previous to the large clocks designed by me have had the Roman numerals. I expected much criticism when dials were put up without these numerals, but strange to say, there is not one person in 100 who ever notices that there are no numerals, and no one has ever yet criticised the arrangement. (The first dial with such markings was designed by Arch. Kees, Minneapolis.) The truth is that these spaces and especially the numerals count for little on a clock face. No person over ten years of age would ever mistake the time of day to the extent of more than two or three minutes, if there were no marks whatever on the face of the dial. It is the hands which tell the time; therefore, they must be large and prominent. The hands of this clock are of such construction and of such importance that their description is necessary. They are, therefore, shown in *Fig. 15* taken from a photograph where the hands were set up against a wall, one of them not being completed. The minute hand is 12 feet in length and the hour hand in same proportion. It will be noticed that the hour hand is much heavier than the minute hand and of entirely different form, so that the two can never be mistaken, one for the other. The hour hand is nearly 2½ feet across at the center. These hands require heavy counterbalances, which are not shown in the cut. The sheathing of the hands is made of sheet copper, the hands being elliptical in form. The centers are supported by rigid bronze framework, which is shown in the unfinished hand. The shafts of the hands are trussed, as shown by v-shaped longitudinal braces on each half, the point of the v's on each half meeting at the center, forming an X-truss for the whole hand. The hands are so wide that supplementary transverse V-shaped trusses are also required.

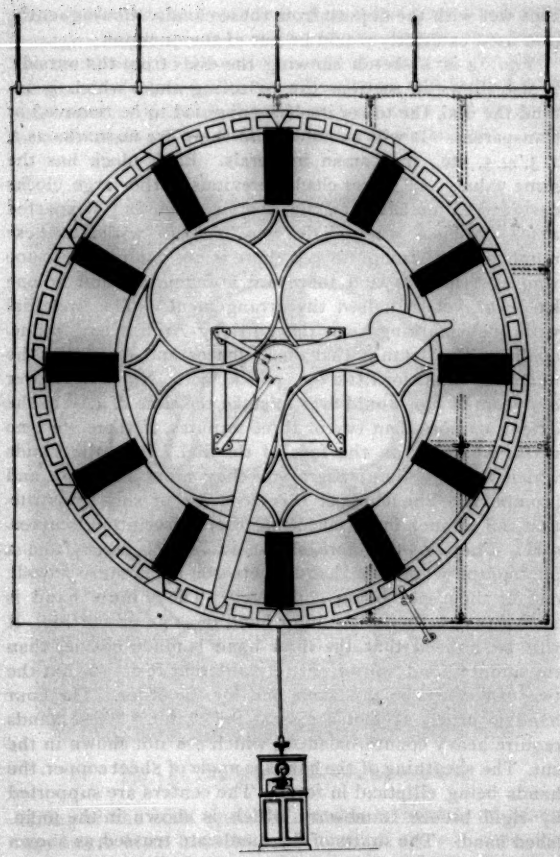

FIG. 14.—Sketch of dial, etc., from without.

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The hands are made elliptical so as to oppose as little resistance to the wind as possible. Notwithstanding these hands are made as light as rigidity and durability will warrant, they weigh with the counterbalances an average of 250 pounds each, the hands for the four dials weighing 1 ton. These hands are supported by a phosphor-bronze shaft 2½ inches in diameter and 5 feet long. As the minute arbor of a clock is always inside of the hour arbor, the minute arbor is also supported by roller bearings at each end. What is called the cluster, or the gearing which reduces the movement from that of the minute shaft to one-twelfth for the hour shaft, is rigidly fastened to the framework, the whole being supported, as shown in *Fig. 11*, by a solid frame which is about 30 inches behind the dial, having braces which go forward to support the axis and the cluster movement at the outer end. A framework of horizontal and vertical beams supports the dial against wind pressure, this support being made at twelve points. Besides being bolted to the ironwork of the tower, the edges of the dial frame are thoroughly bracketed to this ironwork.

In order that the clock may be of value for the whole twenty-four hours, of course it is illuminated, and in this particular it has some very novel features. Very many attempts have been made to illuminate clock dials properly without getting shadows and in only a few instances has it been successful. There hangs from a beam above, by means of rods, as shown in *Fig. 14*, a reflecting frame or sheet. This sheet is 25 feet square and presents a smooth surface toward the dial, the back of it being thoroughly stiffened by angle irons, as shown by the dotted lines in the figure. The same sheet is shown edgewise in *Fig. 11*, the supporting beam at the top being cross-sectioned and the studs below fasten it to the supporting beams to prevent its swinging. This sheet is first given one coat of red lead, two coats of white lead and one coat of white enamel. It is perforated for the insertion of 150 incandescent electric lights having special sockets. These lamps can be put in from the rear. This sheet hangs about 2 feet back of the dial and there is nothing intervening to form shadows.

It requires 600 electric lights, or 50 horse-power, to illuminate. The illumination is the best of any clock dial in the world. The turning off and on of these lights is entirely automatic, and the arrangement, together with some other parts, is shown in *Fig. 16*. *B A* is a four-pole rotary switch, having a capacity of 500 ampères. The four knives are fastened rigidly to the same axis as the lever *i* with a heavy ball. *T* is an expansible chamber with flexible diaphragm,

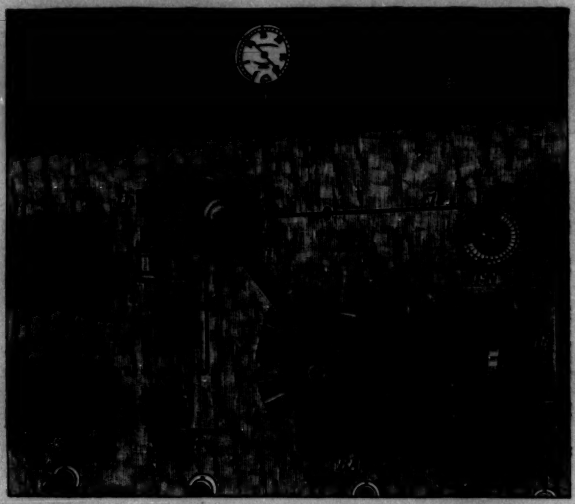

FIG. 16.—Illuminating current switch with controller.

similar to those used on the dial movements. The piston operated by this diaphragm is fastened to the lever *i*, through the connecting rod which is slotted to give lost motion, as shown. When air enters the chamber *T*, it pushes upon the piston, until the lever *i* with its ball is brought to the vertical position. As it passes from the vertical position, the weight of the ball makes it fall to the right, which suddenly makes the four connections. When

the compressed air is exhausted from *T*, the lever is again brought to center and in like manner falls suddenly, breaking connection at the four points. The air is admitted and released from *T* by the device *T N*, which is operated by the same air pressure each minute which operates the four dial movements. The index shown partially in black, partially in white is for twenty-four hours, the lighter portion representing day. The relative length of day and night are adjustable and are changed each week by the revolution of this index. The chamber *T* is filled and exhausted once in

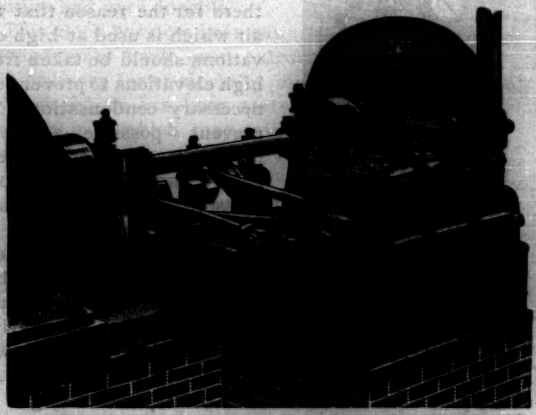

FIG. 17.—Electric air compressors.

twenty-four hours; in other words, the 600 lights are thrown in in the evening and out in the morning automatically. In the same case with this device is the city schedule for street lighting and the clock lights according to the city schedule. On the same marble slab and in the same case there are shown in *Fig. 16* other devices which it is unnecessary to describe particularly. *L D* is a governor for the air pressure, so that it never varies but 2½ pounds, the compressor stopping and starting with those limits. *B* and *C* are starting boxes for the electric motors. Having described the

dials and supports, hands, etc., I would say that the four dials, their reflecting sheets and supporting framework weigh 48 tons.

I have spoken of the compressed air being produced by electricity and that there are also hydraulic air compressors for supplementary work. I deem it unnecessary to minutely describe these devices. Suffice it to say that *Fig. 17* shows the electric air compressors which are located in the dial room, 362 feet above the ground. They are placed there for the reason that the air which is used at high elevations should be taken from high elevations to prevent unnecessary condensation. To prevent possible accident, there are two independent electric motors for these compressors. In general they work together. If there be an accident to one of them and it should stop, the other continues to do the work just the same, either one having more than twice the power required to do the work. As the electric current might be cut off at some time for some purpose, there are connected with the system and located in the engine room of the building three hydraulic air compressors with fittings, shown in *Fig. 18*. These are automatic in their action, so that they do not move when the electric air compressors are at work. Should the electric compressors fail for any reason, the hydraulic air compressors take up the work and have ample capacity. It will be noted that there are three of these. The three are con-

FIG. 18.—Hydraulic air compressors.

nected to two independent water lines, one of these water lines running directly from the city reservoir to the City Hall without any connections; consequently, there is very little liability of an accident happening to it. These hydraulic air compressors are so arranged that, should the water supply fail from either source, the other will do the work. Should either one of the hydraulic air compressors fail to do the work, the others have sufficient capacity. The probability, therefore, of the required air pressure failing is extremely small. As will be seen, the entire mechanism of this pneumatic clock is very simple, very positive and very durable.

This clock has now been running for two years and the derangements have been extremely few, much less than with ordinary tower clocks of much less magnitude. It is so arranged, as has been stated, that there are duplicates for every part which may fail. If the astronomical clock needs cleaning or adjusting, the work is taken up by the auxiliary clock, or *vice versa*. Owing to any derangement of the dial mechanism, only one dial needs to be stopped at a time and the failure of power is almost impossible.

Stated Meeting, held Wednesday, October 17, 1900.

ALUMINIUM AT THE PARIS EXPOSITION (1900).

By Prof. Joseph W. Richards,
Member of the Institute and delegate to the Exposition.

The five international exhibitions held in Paris, since the first, in 1855, have served as landmarks in the history of aluminium. The Palais de l'Industrie, which was demolished last year to make room for the new Art Palaces, housed the first exhibition of 1855, and in it aluminium made its first public appearance in the shape of a bar, lying on black velvet in a glass case, and labelled "L'argent de l'argile," "the silver from clay." Its production had been difficult, in a chemical laboratory, and it practically

had no price, for it was not produced then in a commercial way. That bar cost probably more than its weight in gold. But the possibilities which it stood for appealed strongly to the French mind, and the Emperor gave St. Claire Deville "carte blanche" to develop these possibilities into an industry.

The exposition of 1867 found an established industry to be represented. Deville had perfected his sodium process, and the metal was being sold commercially at the rate of $12 a pound and to the quantity of 1,000 kilograms (1 long ton) a year. It was exhibited as sheets, wire, foil, manufactured goods, polished and engraved, helmets, field-glasses, telescopes—in short, for such articles in which lightness was a prime consideration and cost secondary. The important alloy with copper-aluminium bronze was then shown for the first time.

The 1878 exhibition marked only a moderate expansion of the industry. The yearly output had nearly doubled, but the selling price was the same, and the assortment of goods made from it was hardly larger than in 1867. In short, the industry was nearly at a standstill; the limit of applications of the metal at the price at which it could be furnished by the Deville process had nearly been reached. Many of the expectations which were born of the previous exhibit had been disappointed, and but few new ones realized.

The 1889 exhibition marked a period of revolution in the industry. Castner and Netto, by new and ingenious processes, had made metallic sodium, the reducing agent of Deville's process, at a greatly reduced cost, and had thereby largely reduced the cost of producing aluminium. New life was thus put into the industry, the yearly output had increased to 71 tons and the selling price of the pure metal had decreased to less than $5.00 per pound; in fact, that very year it fell to nearly half that figure. Besides this, the electric processes of Cowles Bros. and of Héroult were furnishing aluminium in copper and iron alloys, but not the pure metal, at even lower prices.

The industry was finely represented at that exhibition,

as befitted its rapidly-increasing importance. The French Deville process, and the two new Castner and Netto processes, were large exhibitors, and the Cowles alloy products were shown. The features of this display were the large masses, ingots, sheets, etc., of pure metal, the largest quantity of aluminium ever brought together in one place up to that time. The uses of aluminium in making solid steel castings, aluminium brass, bronzes and light alloys of hardened aluminium, were among the novelties.

The last year of the century finds the industry upon an entirely different basis. From an annual production of 70 tons it has risen to the relatively enormous figure of 7,000 tons; from a price nearly $5.00 a pound, to the almost incredible figure of 30 cents. The seeds of this revolution were already germinating in 1889, for in that year pure aluminium made electrolytically by Hall in America, and Héroult in Europe, began to undersell the product of the sodium processes, and two years later the sodium processes were distanced and driven out of the business. The pure aluminium shown in 1889 was all made by the sodium process; that shown this year was as exclusively electrolytically produced.

It is almost needless to say that this decrease of price to less than one-tenth of its value in 1889 has been the prime cause of the great demand for the metal. Every decrease in price has opened up the way for larger and novel uses. Many an experimenter has reported of aluminium: "It is most admirably adapted for this purpose, and *when its price shall have been reduced*, etc., etc.," and has waked up a year or so later to the fact that his hoped-for reduction of price had occurred and that the application he had discovered was then possible. The same is true now, as then; possible uses for large quantities of aluminium are now known, which the probable reduction in price during the next five or ten years will convert into actual uses.

Such being the present facts with regard to output, prices and applications, we can state with exactness that the aluminium industry is now, at the end of the century, upon a strictly normal commercial basis. Aluminium is now as really

a metal of every-day life as silver, nickel, mercury, copper, brass, tin, zinc, lead or iron, though not to the same degree as several mentioned. In the United States, in 1898, only pig iron, copper, lead and zinc were produced in greater quantity than aluminium, and only pig iron, copper, lead, zinc, silver and gold surpassed it in value of output. Nickel, mercury, antimony, bismuth and tin were all surpassed. When we wish to make a given object in metal, it can be made cheaper in aluminium than in anything else, excepting zinc, lead or iron; brass, copper and all the other metals are dearer.

Bearing these facts in mind, it can readily be understood that a complete exposition in one or even in half a dozen exhibits of all the present uses of aluminium was not to be expected. The aluminium exhibit was in reality scattered through all parts of the immense exhibition. In electrical apparatus it was frequently used in place of copper; in the machinery exhibits its use was general in parts of light-running machinery, and frames and cases of auto-vehicles; in optical, photographic and general physical instruments the applications were so general as to defy enumeration; while possibly one-half and probably a still greater proportion of all the steel exhibited and all the steel used in and around the exhibition had had aluminium used in its manufacture to secure soundness of the ingots.

The special exhibits of aluminium represented, therefore, only a fraction of the almost innumerable applications to which aluminium has really attained; and, while mostly satisfactory in themselves, cannot be considered as alone representing fairly or completely the whole industry. By themselves these exhibits were scarcely as pretentious as those of 1889, yet they represented an industry 100 times as large. Taken together with the other applications of aluminium to be seen all over the exhibition, they give an adequate idea of the extent to which aluminium has entered now into daily use.

The firms now producing aluminium are the Pittsburgh Reduction Company, Niagara Falls; the Cowles Electric Smelting and Aluminium Company, Niagara Falls;

the British Aluminium Company, at Foyers, Scotland; the Aluminium Industrie Actien Gesellschaft, at Neuhausen, Switzerland; the Société Electrometallurgique Française, at La Praz, Savoy; the Société Industrielle de l'Aluminium, at St. Michel, Savoy. This year will also see put into operation a new plant of the Pittsburgh Reduction Company on the St. Lawrence River, Canada, and two new plants of the Neuhausen Company, one on the Rhine at Rheinfelden, Germany, the other at Lend-Gastein near Salzburg, in Austria. The establishments already in operation have capacity of 34,000 horse-power, capable of producing 7,000 tons of aluminium a year; with the additions referred to, the totals will be 47,000 horse-power and 10,000 tons annual capacity.

The exhibits in detail were as follows:

The British Aluminium Company, of London, had two large exhibits, the one on the ground floor dealing more with the crude metal, the one on the first floor with manufactured articles. Besides a fine display of sheet, rods and wire, objects of special interest manufactured by various British firms were shown. There was a large still, with hood and condensing apparatus, by Storey & Sons, built for use in distilling acetic acid. Several of these are in use in England, doing satisfactory work. The workmanship was very good. A portable water sterilizer, specially designed for army use, weighing 25 pounds and capable of producing 200 gallons of good drinking water daily. Some of these have been put to use in South Africa this year. A Derby firm showed a dog-cart with aluminium body and shafts, and spider-like steel wheels, which was a miracle of lightness combined with adequate strength. Mr. Chatterton, of the Madras Industrial School, sent three large vases and a fine panel, in Indian repoussée style, which were models of fine workmanship and artistic design. The Indian workmen take very quickly to aluminium in place of brass and copper, and the manufacture of culinary utensils for native use is assuming large dimensions. Various other British firms showed hardware, furniture trimmings, ecclesiastical furniture and many other lines of manufactures, all of excellent workmanship.

The firm received a gold medal, and a silver medal, in addition, was awarded to the managers of each of its four works.

The Société Électrometallurgique Française, whose works is at La Praz, Savoy, had the next most important exhibit. Besides the usual articles to be expected, were to be seen many novelties. Samples were shown of the military equipments adopted by the French army, some of which had seen severe service in Madagascar. Automobile castings for frames, motor cases and wheels were very much in evidence; also a motor carriage body of sheet metal weighing only 45 kilos. There was a good display of electric cables for power transmission; also various patterns of sleeves for connecting and joining rods and cables. A large funeral wreath of stamped leaves, laurel and oak, painted, recalls a European custom which is unfamiliar here. The making of such aluminium wreaths has grown to a considerable business in France and Italy.

The Société de l'Aluminium, working the Hall process at St. Michel, Savoy, as also the Pittsburgh Reduction Company in America, and the Swiss Society at Neuhausen, were but meagerly represented.

Aside from the above-named producers of aluminium, many users of the metal in particular ways were exhibitors. In the line of culinary utensils, the Griswold Manufacturing Company, of Erie, Pa., and the Wagner Manufacturing Company, of Sidney, O., fittingly represented the great interest which Americans take in this most practical application to every-day life. In electrical appliances, many firms in the electrical department showed switchboards, motor frames, motor cases, lamp shades, reflectors, search-lights, etc. In the department of scientific instruments, its use was general for balances, field glasses, telescopes, theodolites, photographic cameras, and parts of many delicate instruments. Mr. Levy, of Philadelphia, used it exclusively in the construction of his apparatus in which he etched plates by his acid-blast process, using dilute nitric acid. Chardonnet's machine for making artificial silk was constructed largely of aluminium for the same reason, since the

nitric acid used corrodes almost every other metal which might be used. Escher, Wyss & Co., of Zurich, showed a small aluminium naphtha launch and engine parts. Their work was solid and durable, but lacked finish.

Maxime Corbin, of Paris, showed some remarkably fine large castings for parts of auto-vehicles and motor mechanism. For instance, a dynamo frame complete, weighing 185 kilos (407 pounds), a cannon carriage trailer weighing about half as much, for a mountain field-piece. His large dynamo pulleys are claimed to be lighter and stronger than wood, and do not slip. This foundry turns out seven tons of castings a month, the larger part of which are for electrical and automobile purposes.

Japy Frères & Co., of Paris, showed a large assortment of army equipments; and E. Legros, of Paris, culinary utensils. Many other small firms displayed miscellaneous articles.

A distinctive feature of the present state of application of aluminium is the development of the hard, strong, light alloys. The Albradium Syndicate, of London, showed one which is a little lighter in color than aluminium, and applied to numerous mechanical uses. The Partinium Company, of Paris, had a large display of their tungsten-hardened alloy in culinary utensils, military equipment and motor cases and frames. The castings were very clean and true, and are of great value if as strong as is claimed—50,000 pounds per square inch tensile strength. The latter claim is probably exaggerated, but it is a fact that the best of these light alloys are as strong as gun bronze, section for section, and work as easily as brass.

The Goldschmidt process of producing many rare metals by ignition of their oxides with aluminium powder was finely represented in the German section. A large case was filled with quantities of pure chromium, tungsten, manganese, and the ferro alloys with these metals, and also with titanium, boron and molybdenum. The collection was unique in its way, and shows the process to be in regular commercial application. A Philadelphia firm has recently made arrangements to work the process in this city.

In the line of working aluminium, the Heraeus process of welding aluminium deserves to be highly spoken of. It is the invention of W. C. Heraeus, of Hanau, Germany, and was represented in the German section by a collection of wires, rods, sheet vessels and urns, with perfectly welded seams. The process is operated without solder or flux of any kind, and consists, according to the inventor, in merely cleaning the surfaces to be joined, laying together, heating carefully to the temperature at which the metal commences to soften, keeping at that temperature and meanwhile hammering together to a perfect weld. The process is thus seen to be that of autogeneous soldering. The inventor lays stress on the fact that the temperature must be kept constant; that if it rises too high the metal becomes short or granular, and also commences to oxidize, which conditions defeat the welding. It is merely a question of maintaining the joint by a blowpipe at the proper temperature of incipient softening and hammering together to a weld.

The samples shown were certainly very well done, and the process opens up a new era in the methods of working aluminium.

On the CLASSIFICATION of CRUDE PETROLEUMS.*

By S. F. Peckham.

In the famous report made in 1855 by Prof. Benjamin Silliman, Jr., upon the petroleum of Venango County, Pa., he says, while commenting upon the different boiling points of the different fractions obtained by fractional distillation:

"The uncertainty of the boiling points indicates that the products obtained at the temperatures named above were still mixtures of others, and the question forces itself upon us whether these several oils are to be regarded as *educts* (*i. e.*, bodies previously existing and simply separated in the

* Read at the Petroleum Congress, held at Paris, France, August 25, 1900, and revised for publication in the *Journal*.

process of distillation), or whether they are not rather produced by the heat and chemical change in the process of distillation."

Further on in the report, when discussing one of the heroin distillates, he says:

"The paraffine with which this portion of the oil abounds does not exist ready-formed in the original crude product, but it is the result of the high temperature employed in the process of distillation, by which the elements are mostly arranged."

* * * "Associated with paraffine are portions of a very volatile oil, *eupione*, which boils at a lower temperature, and by its presence renders the boiling point of the mixture difficult to determine."[1]

Previous to the date of this report the naphtha of Amiano had been examined by De Saussure in 1817,[2] and the maltha of Bechelbronn had been examined by Boussingault in 1837.[3]

Up to the time Professor Silliman made this report, petroleum or rock oil had been regarded as a species by both geologists and chemists. As late as 1859 Dr. J. S. Newbury wrote upon "The Rock Oils of Ohio,"[4] and in 1862 Dr. T. Sterry Hunt had written "On the History of Petroleum, or Rock Oil,"[5] basing his discussion on his experiences in Canada.

Still later, in 1876, Dr. J. Lawrence Smith concludes that Professor Silliman, in 1855, was the first person who observed the phenomena attending the destructive distillation of petroleum.[6]

It is now believed that Pelouze and Cahours, in 1863, examined Canadian petroleum.[7] At the same time, and later, Warren alone, and associated with Storer, confirmed the results obtained by the French chemists, and obtained by means of Warren's superior process of condensation a more complete insight into the composition of the hydrocarbons constituting American and Rangoon petroleum. These results, however, were qualitative rather than quantitative, the various substances isolated being practically the same in each of the researches mentioned.

The conclusion followed naturally that the crude oils varied in character as the proportions of the same materials varied in the different mixtures. The idea that the various substances isolated were products and not educts contributed to this conclusion.

In the memoir written in 1868 by C. M. Warren, and published after his death in 1896, Warren proceeds to criticise the results obtained by Pelouze and Cahours, Ronalds, and others, in comparison with his own, and apparently assumed that the crude material upon which these different parties worked was identical.[8] If, as has been asserted, Warren worked on petroleum from the vicinity of Titusville, Pa., and the French chemists worked on Canadian petroleum, it is not surprising that the results obtained by the different investigators were unlike.

It was my privilege, during the years from the autumn of 1866 to 1872, to be on terms of familiar acquaintance with C. M. Warren. A more delightful friend never existed; yet, he was a man who held his opinions with great firmness. He had converted thousands of barrels of petroleum from the wells of Western Pennsylvania into commercial products. He knew that these wells, though drilled many miles apart, furnished oils substantially alike. Moreover, he had made that crucial test, as he supposed; he had destructively distilled menhaden-oil soap, and obtained therefrom petroleum-like compounds. To him petroleum was petroleum, for when I took into his laboratory, in which he and Storer had conducted their now classical researches, the samples of crude petroleum that I had brought from California, he listened with an amused incredulity to my assertions that I had in the cans a new species of petroleum. It was while I was in the midst of my work that he moved his laboratory to his house in Brookline, and I was obliged to finish the work in Providence. I made frequent visits to Brookline to report progress and showed him my results. He said he had examined Professor Silliman's sample of crude California oil and obtained 50 per cent. of light oils. He admitted with reluctance that his sample had been falsified. When I triumphantly assured him that

by passing gases through Pennsylvania and California petroleums that would deprive them of hydrogen, I could evaporate the first and convert the second into asphaltum, he was still incredulous, and thought my ideas regarding the origin of petroleum expressed in 1868 theoretical, without any substantial basis of fact to rest on.[9]

Although I had no absolute proof thereof, I was firmly convinced in 1868 that the California oils consisted of hydrocarbons containing less hydrogen than was found in those from Pennsylvania. It was then impossible for me to obtain a hearing from any of those engaged in investing money in the production of oil in California. The only man who would listen to me was the late Prof. J. D. Whitney, who wanted to send me to Berlin to work the problems up with Hofmann. Professor Whitney had so exasperated the general public on the Pacific Coast by his persistent iteration of the truth regarding petroleum and other interests that they sent him and his geological survey out of the State.

In 1872 Dr. J. S. Newbury published in the *American Chemist*, II, 427, his "Notes on American Asphaltum,"[10] to which I replied.[11] He spoke of the tar springs of the Southwest as springs of heavy petroleum, while I maintained that maltha, or mineral tar, was not petroleum. Meeting Dr. Newbury, a short time after I had published my paper, he showed me his large collection of specimens of petroleum from all parts of the world, and challenged me to put my finger on any specimen, from the lightest to the heaviest, that would not mark a purely arbitrary distinction. With Dr. Newbury, petroleum was petroleum, the only difference in specimens being that some were light and some were heavy.

When, in 1880, I was engaged in collecting the statistics for my report on petroleum to the Tenth Census of the United States, I encountered two significant facts: (1) The investigators of Russian petroleum had discovered that the hydrocarbons that made up the bulk of Russian petroleum were not paraffines with the general formula $C_nH_{2n} + 2$, but additive benzoles with the general formula C_nH_{2n}; (2)

a correspondent reported that the refiners of California petroleum were not making an illuminating oil that could be sold in competition with Eastern oil, but were sending their product to Mexico, where they found a less critical market than in California.

This evidence pointed to sharp distinctions in petroleums from different localities. The wells first struck on Oil Creek and the Alleghany River produced a petroleum easily refined into naphtha, illuminating and lubricating oils; and, while the evolution of the technology of these oils required many years, the movement was along certain well-marked lines, wherein no obstacles were encountered to continued success. The process of cracking, discovered by Joshua Merrill, when working on the distillates from coal, was applied with great success to the Pennsylvania oils, but attempts to apply this method of distillation to the California oils were not found to produce corresponding results, although distillation under pressure did increase the yield of light oils.

Returning to the Pacific Coast in the fall of 1893, I was soon informed by Dr. Salathé of his discovery of the nitrogenous basic oils in the crude California oils and their distillates. This discovery gave definiteness to facts already known, and led to important results in the technology of those oils. This discovery, too, revived in my own mind convictions formed many years before, that the petroleums of the Pacific Coast were specifically different from those of the Mississippi Valley, containing different hydrocarbons, producing different hydrocarbons and requiring different treatment for their successful manipulation. This conviction led to renewed attempts on my part to persuade the owners of large interests in California petroleum to have made a careful and thorough examination of their crude material, with a view to determining the chemical constitution of the oil, the nature and value of its products, and the best methods of securing those products by treatment. These gentlemen still remained unconvinced of the value of such work.

Meantime, the value of a scientific examination of petroleum was gaining ground in Europe, and exhaustive analyti-

cal researches were being had upon Russian and other petroleums. The relation and value of these purely scientific researches to technology were gradually recognized and appreciated.

In the United States the production of enormous quantities of Trenton limestone oil, comparatively rich in sulphur, brought to the attention of both chemists and technologists problems that were both new and difficult. These problems led Prof. Charles F. Mabery to take up the investigation of the "Ohio and Canadian Sulphur Petroleums"[12] along lines suggested by the researches of Warren, but with superior apparatus, and by methods brought into use by the labors and experience of the thirty years that had intervened between 1865 and 1895.

The results obtained by Mabery led me, in a memoir published in the *Journal of the Franklin Institute* for November, 1895, to review the generic and specific relations of bitumen. In that paper, that may not be familiar to this audience, I showed that, down to the middle of the present century, the ancient, medieval and modern world had known no generic relation between solid, liquid and gaseous forms of bitumen, but had regarded natural gas, petroleum or rock oil, maltha or mineral tar, and asphaltum, as things by themselves, with neither specific nor generic relations. I then determined that such a classification is purely arbitrary, depending entirely on merely physical accidents, which in no case exhibited either chemical or geological relations. I further urged that the researches of chemists for the then last thirty years had shown that bitumens had generic relations that embraced all forms of bitumen, in the widest sense, and specific relations that embraced all forms of bitumen possessing, within a certain range, the same chemical composition. I then suggested that, while it was possible to regard all forms of bitumen, either gaseous, liquid, semi-solid or solid, as constituting the genus *Bitumen*, it was equally certain that under this genus were to be found several well-defined species that embraced in some instances only the gaseous and liquid forms, like the Pennsylvania and Ohio oils, in other cases all of the

forms, like the Canadian and California oils, with still others, like grahamite, albertite, gilsonite and Trinidad pitch, that were always solid. I further called attention to the fact that Prof. J. D. Dana had apparently regarded petroleums as rocks rather than species, as he, in his "System of Mineralogy," had inserted Warren's paraffines and isoparaffines as species, while he had also made albertite, grahamite, etc., species. I then showed that there were a number of bituminous minerals that were, strictly speaking, rocks that consisted of loose sand or rock impregnated with bitumen, the bitumen being in some cases a separate species and in other cases referable to a species that usually existed in some of the common forms of bitumen.

I then suggested names for several of these species of bitumen, calling Trinidad pitch *parianite*, the Pennsylvania paraffine petroleums, *warrenite*, the Ohio and Canada sulphur petroleums, *maberyite*, and the California nitrogenous oils, *venturaite*.

With this long preamble, largely consisting of personal reminiscence, for which I crave the indulgence of this audience, I would suggest that the mass of materials now at the disposal of the scientific men of all nations should be arranged according to some system that shall be adequate to classify all of the materials now accumulated and sufficiently elastic to receive the acquisitions of the future.

As this subject has occupied my thoughts for many years, I may be pardoned for offering some suggestions. I believe that an adequate system must embrace all forms of bitumen and cannot be confined to petroleums alone. It must begin by creating a sharp distinction between pyrobitumens and their anthracitic residues and true bitumens and their anthracitic residues. This distinction was first made by the late Dr. T. Sterry Hunt as long ago as 1863,[13] a distinction that has been too much lost sight of, and which is fundamental. This distinction is based on the fact that coals, schists and shales with their residues are nearly as insoluble in the solvents of bitumen as in distilled water; while all true bitumens are miscible with or

almost wholly soluble in chloroform, a test that at once determines their relation to pyrobituminous minerals. The so-called asphaltic coals are not coals at all, but are the anthracitic residues of bitumens.

Having distinguished bituminous from non-bituminous minerals, the classification should, in my judgment, proceed upon the basis of chemical composition alone, either from the simple to the complex or the reverse. If from the simple to the complex, the first group or family would contain pure natural hydrocarbons, as occurring in nature, not separated in the laboratory. A second group might include compounds of carbon, hydrogen and oxygen; a third, compounds of carbon, hydrogen and sulphur; a fourth, compounds of carbon, hydrogen and nitrogen. A species should fall naturally under these groups, without regard to its physical condition, whether solid, liquid or gaseous, these physical conditions being merely accidents of occurrence, as I have elsewhere shown. Bitumens that are found to be mixtures of several of these groups, characterized by the predominance of one of them, may be classed under the group to which they are most closely allied.

In this way a classification may be effected for the purposes of pure science, and more particularly mineralogy, that can be readily modified for the purposes of technology. If it is urged that such a system is too intricate for the Petroleum Exchange, and that commercial differences exist among petroleums and other forms of bitumen generally of like composition, as, for instance, the oils of the Bradford field and those of the Lower country, I insist that commerce always has, and I presume always will, assume a lofty intelligence above the scientific world, of which the scientific world can take no note, because there are no points of contact between the two spheres of human activity.

There is, however, a limit to this divergence of interest and purpose that appears when a petroleum chemist is called upon to examine petroleum from a new locality and report upon its possible relations. It is, therefore, pertinent to inquire in what manner a new petroleum may be reported. There are now four, if not more, types of commercial petro-

leum that rank relatively as follows, not intrinsically, but in commerce:

(1) Paraffine petroleums.
(2) Russian petroleums.
(3) Sulphur petroleums.
(4) Nitrogen petroleums.

The differences in these crude oils may certainly be regarded as specific, and they have been established upon the results of very elaborate analytical researches. Perhaps for commercial purposes the bestowal of specific names upon these varieties would not be understood or appreciated, but for the purposes of the laboratory they might be.

There is, however, in view of the knowledge we now possess, one aspect of this question that can well be considered by this congress and definite action urged upon both the experts in petroleum and their clients. This aspect is the extent to which the expert or the client is justified in demanding an examination of a specimen from a new locality, which shall be made by the elaborate analytical methods employed in the researches upon petroleum conducted during the last ten years.

My own judgment is that such an examination is fundamental, for such an examination is of importance from purely commercial considerations, to determine to which of the classes above enumerated any given specimen of petroleum belongs, for the oil may be in demand as a fuel, or for the manufacture of illuminating oil, or for the manufacture of lubricating oils. For either of these purposes it cannot be denied that the paraffine petroleums easily take the lead, as it requires no argument to prove that the more hydrogen gas is combined in any given liquid the greater number of heat units a pound of it will render available on combustion. Again, if it is desired to convert the petroleum into naphtha, high-grade kerosene and reduced oils, the paraffine petroleum will yield the largest return. Again, if the design is to treat the oil by cracking, the balance-sheet will show the largest profit in the conversion of paraffine petroleums.

Chemical science has not yet shown us how to add hy-

drogen to compounds deficient in that element in any large way. In the laboratory of nature, by the alchemy of the sun, those mysterious processes go forward that rob hydrogen of its oxygen, and store it away for the service of man. I am not a believer in the chemical theories of the origin of bitumens.

If the paraffines are placed in the first rank for reasons based on pure science, the additive compounds of the benzole series should take rank as superior to the naphthenes, and they in turn as superior to the olifines, if the material is to be used simply for fuel purposes. For illumination any of them are decidedly inferior to the paraffines; if for cracking, the inferiority is still greater.

If sulphur is added by substitution to either the first or second class of petroleums, objectionable features are increased. Sulphur in equivalent proportions is greatly inferior to hydrogen as fuel. It is, however, in the manipulation of sulphur petroleums for illuminating purposes that difficulties appear. If a certain proportion of a paraffine petroleum is converted by substitution of one atom of sulphur for two atoms of hydrogen, and this atom of sulphur is afterwards wrested from its combination, the result is an olifine and not a paraffine.

It requires no argument to show that the more nitrogen an oil contains the less its value will be for fuel or illumination. The basic oils may be found in extremely small quantities even in paraffine petroleums, but when the percentage becomes large in an oil containing benzoles, and a small percentage, if any, of paraffines, the value of the products that may be obtained from such a petroleum for illumination becomes seriously impaired.

A crude petroleum is not necessarily determined as belonging *strictly* to either of these types, but it must, I think, approximate one of them. It therefore becomes of importance not only from the standpoint of pure science, but from that of commercial utility as well, to ascertain by the most careful examination the composition and relations of the various compounds that constitute the sample under examination. This course, while involving more time and

expense, is, in the end, both more economical and more satisfactory than the time-honored expedient of distilling a pint from a glass retort and dividing the distillate into fractions of certain specific gravities, but of unknown composition.

NOTES.

[1] Report on Rock Oil or Petroleum. B. Silliman, Jr., New Haven, 1855; *American Chemist*, 2, 18; *Monit. Sci.*, No. 366; *Am. Jour. Gas Lighting*, 16, 83; *Wagner's Jahresbericht*, 1872, p. 848.

[2] *Bibliothèque Universelle*, 4, 116; *Ann. de Chimie et de Physique*, II, 4, 314–340; *London Jour. of Science*, 3, 411.

[3] *Ann. de Chim. et de Phys.*, II, 64, 141; *Jour. of the Franklin Inst.*, 24, 138; *New Edinburgh Philos. Jour.*, 22, 97.

[4] *Ohio Agricultural Report*, 1859 (2d s.), p. 605.

[5] *Reports of the Smithsonian Institution*, 1862; *Canadian Naturalist and Geologist*; *Am. Jour. of Science*, II, 35, 157; *Chemical and Geological Essays*, 1875, pp. 169, 176–179.

[6] *Reports and Awards, International Exhibition*, 1876. General Report of the Judges of Group III, p. 155.

[7] C. F. Mabery, *Proc. Am. Acad. Arts and Sciences*, 32, 121–176.

[8] C. M. Warren, *Proc. Am. Acad. Arts and Sciences*, 31, p. 56.

[9] *Proc. Am. Philos. Soc.*, 10, 445. *Geo. Survey California*, Geology, II, Appendix, pp. 73–90.

[10] *Am. Chemist*, 2, 427; *Chem. News* 28, 46; *Am. Journal Pharmacy*, IV, 2, 313.

[11] *Am. Chemist*, 4, 6.

[12] *Proc. Am. Acad. Arts and Sciences*, 31, 1.

[13] *Loc. cit.*

ELEMENTARY GRAPHICS AND GEOMETRY OF THERMODYNAMICS.

By Robert H. Thurston.

(*Concluded from p. 77.*)

Proposition 11.—If any substance is transferred from any one given thermodynamic state to another defined condition by a known path, and if the same transfer be effected by a second and different path, the difference in the quantity of heat absorbed or emitted in the two cases is measured, on a diagram of energy, by the area included between the lines representing the two paths; which area measured the difference in work done. *Fig. 7.*

Let A and B represent the two given states, and $A\ a\ B$, $A\ b\ B$ the two paths taken in the process of transfer. Then the difference in the amount of heat absorbed or emitted is measured by the area $A\ a\ B\ b\ A$, included between the paths $A\ a\ B$ and $A\ b\ B$.

For, let $A\ D$ and $B\ C$ be isentropic lines through A and B, indefinitely extended toward X; then the work done and the heat absorbed or emitted are measured, when the route $A\ B$ is taken, by the areas $A\ a\ B\ x_2\ x_1\ A$ and $A\ a\ B\ C\ \ldots\ x\ \ldots\ D\ A$. If the route $A\ b\ B$ is taken, these quantities are measured by $A\ b\ B\ x_2\ x_1\ A$ and $A\ b\ B\ C\ \ldots\ X\ \ldots\ D\ A$. The differences, both in work done and in total heat absorbed or emitted, are therefore measured by the same area, $A\ a\ B\ b\ A$. Q. E. D.

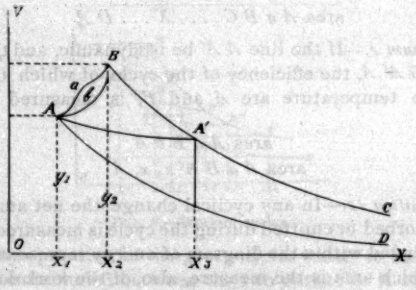

FIG. 7.—External work.

Corollary 1.—The differences in the quantity of heat demanded or surrendered by any working substance in its transfer from one state to another, by different routes, are dependent solely upon the routes taken, and not at all upon the nature of the substance.

Corollary 2.—The proposition above enunciated applies with every form of matter which can be used as a vehicle of heat-energy.

Corollary 3.—The working substance being transferred from one state A to another state B, by one route $A\ a\ B$, and being then restored to its initial state by another route $A\ b\ B$, the difference between the heat absorbed during the

one operation, and the heat rejected during the reverse change, is measured by the thermal equivalent of the work represented by the area $A\ a\ B\ b\ A$ included between the two paths of transfer.

Corollary 4.—The area, on a diagram of energy, included between the two lines of transfer $A\ a\ B$, $A\ b\ B$, and measuring the work done during such a cycle as is represented by its outline $A\ a\ B$, $B\ b\ A$, is a measure of the net amount of heat transformed into work in that cycle.

Scholium 1.—The efficiency of the cycle in which the working substance is transferred from the state A to the state B and is returned from B to A by a different path, along which heat is rejected and lost, is measured by the ratio

$$\frac{\text{area } A\ a\ B\ b\ a}{\text{area } A\ a\ B\ C \ldots . X \ldots D\ A}.$$

Scholium 2.—If the line $A\ A'$ be isodynamic, and the path be $A\ a\ B\ A'\ A$, the efficiency of the cycle, of which the limits as to temperature are A and B, is measured by the ratio

$$\frac{\text{area } A\ a\ B\ b\ A}{\text{area } A\ a\ B\ A'\ x_2\ x_1\ A}.$$

Proposition 12.—In any cyclical change the net amount of heat absorbed or emitted during the cycle is measured by the area included within the diagram of energy representing the cycle, which area is the measure, also, of the work done during the cycle. (*Fig. 8.*)

Let any number of cycles be represented, including in each the points A and B, as by traversing the routes $A\ a\ B$, $A\ b\ B$, the adiabatics $A\ D$, $B\ C$, the isodynamics or isothermals as $A\ B''$, $A'\ B''$, $A''\ C$, or the isopiestic and isometric lines $A\ B'$, $A''\ C$, $B'\ A''$, or others. Then, in all cases, will the net work done, and the net amount of heat absorbed or rejected, be represented by the area included within the lines exhibiting the path of the body on the diagram of energy during the period of such a cycle.

For, let $A\ a\ B\ B'\ A$ be one of these cycles; then will the difference in heat absorbed in passing over the paths $A\ a\ B$ and $A\ B'\ B$, or the difference between the heat absorbed in

the change $A\ a\ B$ and that rejected along $B\ B'\ A$, be alike measured by the work represented by the area $A\ a\ B\ B'\ A$. If a cycle be represented by $A\ B'\ A'\ A$, the net quantity of heat demanded and transformed into work will, similarly, be proportional to the area measuring that work, $A\ B'\ A'\ A$; and similarly of any other cycles, as $A\ b\ B\ B''\ A$, $A\ B'\ B''\ A'\ A$, $A\ B''\ B'''\ A'\ A$, and of the sum, in combination, of any number of adjacent paths or cycles.

Corollary 1.—If, in any heat-engine, heat energy is transformed into mechanical energy by a change of state along a route $A\ B$, and if a less amount is retransformed into heat from mechanical energy by transfer of the substance back to its initial state A along any other route, as $B\ B'\ A'\ A$, the machine produces a net amount of mechanical work, or

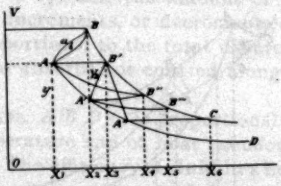

FIG. 8.—Work of cycles.

energy, by operation in the given cycle, which is measured by the area included between the two paths; or it effects a net transformation of work into heat which is the equivalent of such work.

Corollary 2.—When all heat rejected by the working fluid is discharged from the system, the total amount of heat absorbed during the first operation is expended, while the work done remains as before. The efficiency of the fluid in a heat-engine then becomes equal to the quotient of the thermal equivalent of work so done by the total heat expended, *i. e.*, the difference between heat absorbed and rejected, divided by heat absorbed.

Remark.—In all real heat-engines, heat is necessarily thus lost; since a certain amount is always rejected by the engine with the exhaust, and is carried from the system

either by the discharge of working fluid or through the refrigerator, if one be used; this heat is at too low a temperature to be utilized further in the production of work.

Corollary 3.—Internal energy remaining unchanged for any complete cycle, these principles apply equally to gaseous and other working substances, and, in all engines, the net gain or loss of heat, the quantity rejected from the system and the efficiency are determined by the amount of external work done in the cycle; the internal condition of the substance may be ignored.

Proposition 13.—The quadrilateral formed by the intersection of a pair of isothermal lines with a pair of isentropic curves encloses an area, and measures an amount of work

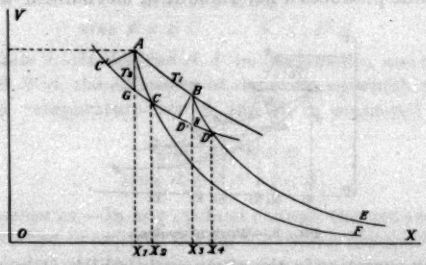

FIG. 9.—Carnot principle.

and of transformed heat which is proportional to the difference of temperature occurring during the cycle so represented. (*Fig. 9.*)

Let *A B*, *C D*, be two isothermal lines, intersected by two isentropic lines, *A C F*, and *B D E*, at *A*, *B*, *C* and *D*.

Then, in any cyclical change, such as *A B D C*, *A* or the reverse, will the extreme range of temperature be measured by the difference $T_1 - T_2$, of the temperatures of the substance when traversing the paths *A B* and *C D*, and the area *A B D C* will be to the total area, *A B D E . . . X . . . F C A*, as the net energy expended or received, and the net amount of heat absorbed or emitted by the substance is to the total heat absorbed. But these quantities of work and heat are pro-

portional to the absolute temperatures at which absorption or rejection of heat takes place, and the areas described thus measure alike differences of mechanical energy and of absolute temperature. Hence the area $A\ B\ D\ C$ is to the total area $A\ B\ D\ E \ldots X \ldots F\ C\ A$ as the difference of temperature, $T_1 - T_2$, is to the initial temperature T_1, and for such changes we have as measuring the ratio quantities of heat,

$$\frac{A\ B\ D\ C}{A\ B\ E \ldots X \ldots F\ C\ A}.$$

Also, the area, $A\ B\ x_2\ x_1\ A$, measures the heat converted into work during the expansion from A to B at the temperature T_1; the area, $A\ B\ D\ C$, measures the diminution, in amount of work so transformed, due to the difference of temperature $T_1 - T_2$; and the amount of this variation is equal for equal increments, or decrements, of temperature, and is thus proportional to the total difference of temperature, and of heat absorbed or emitted, along the two isothermals.

Hence the area, $A\ B\ D\ C$, is proportional both to the difference of temperature and of heat transformed.

Corollary 1.—The efficiency of fluid in a heat-engine working through a cycle represented by two pairs of lines intersecting, the one pair being isothermal, the other isentropic, is measured by the ratio,

$$\frac{H_1 - H_2}{H_1}$$

of the difference of heat absorbed and emitted, along the two isothermals measured from zero, to the total heat present, in the working substance, at the maximum temperature.

Corollary 2.—The efficiency of such a cycle is measured by the ratio,

$$\frac{T_1 - T_2}{T_1},$$

of the difference of extreme temperatures to the maximum temperature.*

*This cycle has already been described as "Carnot's Cycle," its efficiency having been first deduced by Sadi Carnot (1824).

Proposition 14.—The maximum efficiency of any cyclical thermodynamic operation, occurring in a heat-engine, is obtained when the absorption of heat by the working substance takes place wholly at one constant temperature, and rejection occurs wholly at a lower constant temperature, the diagram of energy representing the cycle being composed of a pair of isothermal lines connected by a pair of adiabatic, or isentropic, lines.*

For, in such cycles, the work done by transformation of heat is measured by the area included within the quadrilateral formed by the bounding isothermal and isentropic lines; this area is also a measure of the heat transformed into mechanical energy, and is proportional to the range of temperature worked through. The total expenditure of heat, taking place, as it does, entirely at the higher temperature, is proportional to the maximum absolute temperature.

But the maximum total effect is produced when all the heat transferred is so transferred with maximum range of temperature; and this occurs when all heat is received at the maximum temperature, and all heat rejected is emitted at the minimum temperature, no transfers taking place at intermediate temperatures; this cycle is one in which expansion during the period of absorption of heat is isothermal, and when the compression with emission of heat is also isothermal, the one process taking place wholly at the maximum, and the other wholly at the minimum, attainable temperature.

Corollary 1.—The cycle of maximum efficiency of fluid, in the heat-engine, is a Carnot cycle, and all heat is received at the maximum temperature, while all heat rejected is discharged at the minimum temperature, the transfer from isothermal to isothermal being effected by isentropic or adiabatic expansion, or by some other system of transfer, without final gain or loss of heat.

Corollary 2.—The maximum efficiency of fluid, in the perfect heat-engine, is a function of temperature only and is independent of the nature of the working substance.

*This is "Carnot's Law."

Corollary 3.—The maximum efficiency of fluid in any perfect heat-engine is attained when expansion from the maximum temperature occurs adiabatically, or isentropically, down to the "back pressure," *i. e.*, to the temperature of the condenser, or to that due the atmospheric pressure, accordingly as the engine is condensing, as often with vapor engines, or non-condensing, as with air and other gas engines.

Corollary 4.—If, in the transfer of the working substance from isothermal to isothermal, the change is produced by abstraction of heat instead of isentropic expansion, and by restoration of an equal amount of heat instead of by isentropic compression, the net loss in the two transfers being *nil*, the efficiency remains a maximum, and equal to

$$\frac{T_1 - T_2^*}{T_1}.$$

Corollary 5.—Cycles in which the bounding lines are a pair of isothermal lines, intersected by any pair of isodiabatic lines, along which transfer is effected by the abstraction and restoration of heat energy from and to any reservoir of heat, are cycles of maximum efficiency; and in all such cycles the efficiency and the work done are the same when working between the same limits of temperature.

Scholium 1.—The lines representing transfer from isothermal to isothermal by the use of a regenerator approximate to the isodiabatic form as the regenerator approximates perfect efficiency in storing and restoring of heat.

Corollary 6.—The character of the isodiabatic lines adopted where regenerators are employed, whether lines of constant volume, of constant pressure, or other, or if isentropic transfer occurs between isothermals, has no effect upon the efficiency of the cycle; all give maximum efficiency if the other pair of bounding lines are isothermals of maximum and minimum temperature, the heat absorbed being then proportional to the maximum absolute temperature, that rejected to the minimum temperature, the net work done to the difference, and the efficiency measured by

* The action described would be that of a perfect "regenerator"

the ratio of the range of temperature divided by the maximum.

Scholium 2.—The "regeneration" has no effect on maximum efficiency, but may be so applied as to alter the method of isodiabatic transfer of heat and thus to reduce the volume and weight of the engine of which it forms a part.

Corollary 7.—The Carnot cycle is "reversible," *i. e.*, the operations indicated being reversed and performed in the opposite order, the effects are similarly reversed, the work is converted into heat in precisely the proportion in which, in the direct operation, heat energy is transformed into work.

Corollary 8.—All heat, in such cycles, is either transformed or it is transferred from the one to the other limit of temperature, and rejected at the final temperature.

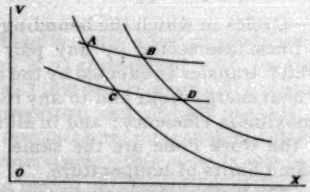

FIG. 10.—"Letting down" heat.

Scholium 3.—The maximum efficiency of the heat-engine is a function of temperatures of receiving and rejecting heat, solely.*

Proposition 15.—In every cyclical change in which heat energy is developed by transformation from mechanical energy, or the reverse, such change is accompanied by a transfer of a definite quantity of heat energy from a lower to a higher temperature, or the reverse (*Fig. 10*).

Let *A B D C* represent a Carnot cycle in which the area *A B D C* measures the amount of heat and work transformed between the temperature T_1 of the isothermal *A B*

*This conclusion is thus reached by another of several distinct lines of deduction.

and the temperature T_2, of the isothermal $C\,D$, the transition from one to the other occurring by the isentropic lines, $A\,C$, $B\,D$. Then will a definite quantity of heat be, at the same time, transferred from the temperature T_1 to the temperature T_2, or from T_2 to T_1.

For, if the course taken be $A\,B\,D\,C$, an amount of heat measured by the area $A\,B\,D\,C$ will be transformed by doing work, and all heat not so transformed and deducted from the total quantity supplied at the temperature T_1, up to the point C, will remain in the form of heat. But, during the process, rejection of heat occurs along $D\,C$ of all heat of compression and at the temperature T_2. The total heat supplied along $A\,B$ is proportional to the temperature T_1, and the quantity rejected is proportional to T_2. The proportion converted into work is

$$\frac{T_1 - T_2}{T_1},$$

and the part remaining,

$$\frac{T_2}{T_1},$$

is rejected at the lower temperature untransformed.

Similarly of any other cycle; the heat transformed into or out of mechanical energy is measured by the area $A\,B\,D\,C$ enclosed by the lines representing the cycle, while all other heat supplied is rejected at lower temperature, or, with the reverse process, all heat not received as transformed work is received in the form of heat at a temperature higher than that of supply.

Scholium.—The proportion of heat rejected in the Carnot direct cycle is the same whether transfer from isothermal to isothermal occurs isentropically or isodiabatically by means of a perfect regenerator.

Corollary 1.—A given amount of work being done in the Carnot cycle by the transformation of a proportion

$$\frac{T_1 - T_2}{T_1}$$

of heat, and with rejection of the proportion

$$\frac{T_2}{T_1}$$

as sensible heat, the reversal of the operation yields unity of heat by the expenditure of the fraction

$$\frac{T_1 - T_2}{T_1}$$

of its mechanical equivalent in work.

Corollary 2.—That cycle of the Carnot type which rejects most heat when worked directly is the most economical cycle when reversed for the purpose of obtaining heat from work.

Corollary 3.—Transformation of energy into heat by means of the Carnot cycle is an efficient method of produc-

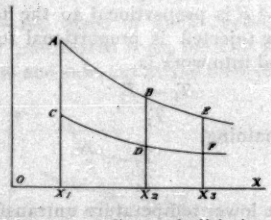

FIG. 11.—Ordinates of adiabatics.

tion of heat of high temperature in an elastic fluid, since it yields unity of heat by the expenditure of but

$$\frac{T_1 - T_2}{T_1}$$

parts of its equivalent in mechanical energy.*

Proposition 16.—In any pair of adiabatic or isentropic lines, obtained for any given gaseous substance, the ordinates at equal volumes are continually proportional. (*Fig. 11.*)

Let the lines $A\,B, C\,D$ be isentropic or adiabatic; then if ordinates $A\,C\,x_1$, $B\,D\,x_2$ and $E\,F\,x_3$ be drawn, intersecting the curves, the ratios of the ordinates will be equal and

$$\frac{A\,x_1}{C\,x_1} = \frac{B\,x_2}{D\,x_2} = \frac{E\,x_3}{F\,x_3}; \quad \frac{A\,C}{A\,x_1} = \frac{B\,D}{B\,x_2} = \frac{E\,F}{E\,x_3};$$

$$\frac{A\,x_1 - B\,x_2}{A\,x_1} = \frac{C\,x_1 - D\,x_2}{C\,x_1};$$

* This principle was recognized by James Thomson.

and the variations of pressure, as well as the actual pressures, are proportional.

For, the areas $A\,B\,E\ldots X\ldots x_1\,A$, and $C\,D\,F\ldots X\ldots x_1\,C$, are proportional to the total intrinsic energies of the substance at the pressures $A\,x_1$, $C\,x_1$; and these areas and energies are proportional to the temperatures and pressures of the gas at A and C; and these areas are thus proportional to their ordinates at their initial points. The same is true of the areas limited by the ordinates $B\,x_2$ and $D\,x_2$, and those ordinates themselves. Since the two curves are isentropic, and, therefore, similar, the total areas are similarly varied by equal variation of volume, and

$$\frac{A\,B\,E\ldots X\ldots x_1}{C\,D\,F\ldots X\ldots x_2} = \frac{B\,E\ldots X\ldots x_2}{D\,F\ldots X\ldots x_2},$$

whence the equality

$$\frac{A\,x_1}{C\,x_1} \quad \frac{B\,x_2}{D\,x_2}.$$

Q. E. D.

Corollary 1.—If the fluid have the same internal energy, in any two or more different states, defined by different pressures and volumes, the work done by indefinite expansion will be the same for all cases, and the changes of pressure and of volume will be proportional to the initial pressures and volumes.

Corollary 2.—The adiabatic, or isentropic, expansion of the fluid, from different initial states of equal intrinsic energy, to any one state, given as to pressure or volume, will yield varying quantities of mechanical energy, and different efficiencies of fluid. Equal intrinsic energies do not imply equal available energy.

Corollary 3.—That initial state which, with the same intrinsic energy, will develop the greatest amount of mechanical energy, with a definitely limited expansion, is that which is marked by maximum initial pressure.

Scholium.—The efficiency of fluid, and the efficiency of engine, in any heat-engine, is made a maximum, using working substances of equal initial intrinsic energy, when that fluid is chosen which possesses maximum initial pressure, the terminal and back pressures being fixed.

Proposition 17.—The difference in the latent heat, of expansion of any substance, expanding between isometrics at constant temperatures differing by a specified amount, is equal to the difference in the mechanical work done, in such isothermal expansion, at the two given temperatures.

Let the fluid expand, at the temperature T_1, from A to B and again at T_2, from C to D, *Fig. 12.* Then will the difference in quantities of heat absorbed in the two expansions be equal to the difference in work done in so expanding.

For, the heat absorbed, in the change from C to A, plus the heat absorbed in expansion at T, between A and B, is equal to that absorbed in passing from C to D and from D to B, provided none is transformed into work; but let the substance work through the cycle $A\,B\,D\,C$; then will the

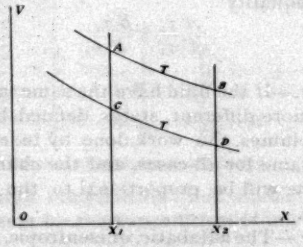

FIG. 12.—Latent heat.

net work done be $A\,B\,D\,C$, the difference between the work, $A\,B\,x_2\,x_1$, done during the expansion on $A\,B$, and $D\,C\,x_1\,x_2$, that recovered by compression on $D\,C$;

$$C\,A + A\,B = B\,D + D\,C + A\,B\,C\,D$$

for the specific heat of constant volume, measuring the variation of heat along $C\,A$ and $B\,D$, is constant, and

$$A\,B - B\,D = D\,C - C\,A + A\,B\,C\,D$$

and this transformation will be in equal amount in whichever direction the change may occur. Therefore, the work done along $A\,B$, which is equal to that done along $D\,C$, plus the difference in work done, $A\,B\,D\,C$, is also equal to that done.

in the inverse direction, along *C D*, plus the net work done in the cycle; and the difference in the latent heats of expansion at the two temperatures is measured by the difference in the work done by expansion at those temperatures.

Proposition 18.—The area included under any isentropic curve, indefinitely extended from any given isometric line, is dependent upon the temperature of the fluid, if gaseous, and not upon its pressure.

For, the area of the diagram so limited is dependent upon the quantity of heat-energy present in the initial state of the substance, and the amount of this energy is measured by the product of the weight of the substance into its

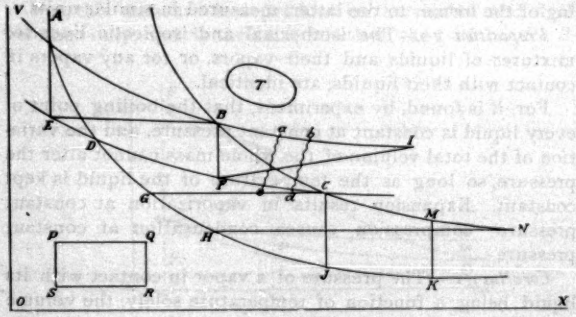

FIG. 13.—Thermodynamic cycles.

specific heat at constant volume and into its temperature, and is, therefore, independent of the pressure.

Corollary 1.—The quantity of heat absorbed in passing from any one state to another by isometric change is the same for equal difference of temperature, whatever the pressures at which the change occurs.

Corollary 2.—Two isothermal lines being drawn and connected by any number of isometric lines, the areas included between the latter and the two isentropic lines drawn through their extremities are all equal.

Proposition 19.—Whatever the form of cycle for any heat-engine, the efficiency of the fluid is measured by the ratio of

the mechanical equivalent of the work represented by its diagram to the total heat supplied to the system.

In *Fig. 13*, let the principal types of heat-engine cycles be represented by the intersection of the several lines, of which *A B I* and *E F C* are isothermal; *B C M* and *A D H K* are isentropic; *E B* and *F I*, *G C* and *H N* are isopiestic; *A E*, *B F*, *C J*, *M K*, *P S*, and *Q R* are isometric; and *T* is a cycle of indefinite and irregular form. Then, in the cycle *A B C D* the system receives heat along *A B* and rejects it along *C D*, giving maximum efficiency. In all others, similarly, the enclosed areas measure the work produced by the stated expenditure of heat, and the efficiency is the rating of the former to the latter, measured in similar units.

Proposition 20.—The isothermal and isopiestic lines for mixtures of liquids and their vapors, or for any vapors in contact with their liquids, are identical.

For, it is found, by experiment, that the boiling point of every liquid is constant at constant pressure, and the variation of the total volume of the whole mass cannot alter the pressure, so long as the temperature of the liquid is kept constant. Expansion results in vaporization at constant pressure; compression causes condensation at constant pressure.

Corollary 1.—The pressure of a vapor in contact with its liquid being a function of temperature solely, the volume of such vapor is entirely arbitrary.

Corollary 2.—The quantity of liquid present in any given weight of a mixture of a liquid and its vapor is determined by the volume occupied and by the temperature, or by the pressure which is a function of the temperature.

Corollary 3.—The density of a vapor in contact with its liquid is determined by its temperature, or by its pressure which is a function of temperature only.

Scholium 5.—The lines of transfer for the case in which change of temperature is obtained by the use of the regenerator are, in the perfect engine, isodiabatic.

Proposition 21.—The internal work done in the variation of potential energy during any change of state of any substance is measured, on a diagram of energy, by the area

included between the two extreme ordinates of the diagram and the isodynamic and isothermal lines passing through the initial point and terminating at the final ordinate.

Let the expanding body pass along *A a B* from the state *A* to the state *B*. Then will the area *A C D A*, included between the isothermal line *A C*, the isodynamic line *A D*, and the ordinate x_2, measure the amount of internal potential energy acquired; while the area *B E F B*, between the isothermal *B F* and the isodynamic line *B F*, will similarly measure this quantity, if the body is compressed by restoration to the initial volume by the same path or any other, as *B b A* (*Fig. 14*).

For, this measure is dependent on the initial and final volumes only, and is the same whether the path be *A a B*,

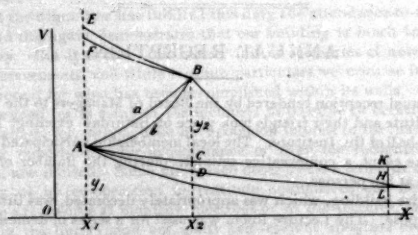

FIG. 14.—Internal work.

B b A, *A C*, *A D*, *B E*, or *B F*. But the route *A C*, being isothermal, all heat transferred is exchanged for work; along *B F*, all heat emitted comes from mechanical energy expended; along *A D*, all heat demanded for internal work is supplied from the original stock of sensible heat, and all heat absorbed is applied to the production of external energy; along *B E*, all heat emitted is derived from external work, and all variation of tension and of temperature is due to transformation of internal potential energy into sensible heat.

Hence, the difference of area *A C D*, or *B F E*, must be due to and a measure of the variation of internal potential

energy between the volumes $O x_1$ and $O x_2$, in consequence of the change $A B$.

Corollary 1.—The areas included between any two isothermal lines $A C$, $B F$, and two isodynamic lines, $A D$ and $B E$, having the same initial point on any one ordinate, and terminating at different points on another ordinate, must be equal wherever the initial point may be situated, the change of volume being the same for both cases.

Corollary 2.—The amount of external work done during the change $A B$ is measured by the difference between the area included between the path $A B$ and the ordinate $A x$, $B x$, and the area $A C D$, the pressures measured by the ordinates to the curve $A B$ being made equal to the sum of external pressure and internal molecular tension.

ANNUAL RECEPTION.

The annual reception tendered by the Board of Managers to the members of the Institute and their friends took place on Saturday evening, December 8th, in the hall of the Institute. The local membership participated very generally in the event, a conservative estimate placing the number of those in attendance at 850 persons.

The entire building, which was appropriately decorated, was thrown open for the purpose. The Lecture Room was used for a series of demonstrations, designed in part for entertainment, and chosen in part for their scientific novelty and interest. The seating capacity of the room was so inadequate that the demonstrations were repeated before two audiences, which thronged the place to the doors.

In the Reading Room, on the second floor, the managers received their guests. The executive committees of the several Sections had vied with one another in the collection of exhibits of scientific and technical interest, and the results of their well-directed efforts were in evidence upon the rows of tables, and upon the walls.

The School Rooms, on the third floor, were open for inspection and were visited by large numbers.

Luncheon was served during the evening in the alcove known as the Committee Room; and, that the fitness of things should not be violated, the musical portion of the entertainment was furnished by the latest scientific novelties, the Graphophone "Grand," and the Electro-Chord Piano. The event realized most satisfactorily the anticipations of the managers, and fully demonstrated that the members of the Institute duly appreciate these occasional opportunities for social intercourse.

The successful outcome of the reception is due to the work of a special committee of the Board of Managers, of which Mr. Henry Howson was the chairman, and to the active co-operation of the executive committees of the several Sections.

Following is a brief account of the proceedings, with a list of the principal exhibits:

Mr. Howson, Chairman of the Reception Committee, opened the proceedings in the Lecture Room with a brief address, referring to the objects which the managers had in view in arranging for this reception, and expressed the great satisfaction of himself and associates with the manner in which the members had responded.

Mr. Howson introduced President John Birkinbine, who made the following address:

MR. BIRKINBINE:—"The satisfaction given two years ago by an evening set apart for greetings between members of the Franklin Institute encouraged the Board of Managers to call you together again and to ask the Committee, with Mr. Howson as Chairman, to make this event as successful as the reception of 1898.

"That the committee has fulfilled this duty the attendance to-night is evidence, and this again demonstrates that our building is much too small for the family. But it is the 'old home,' full of memories of noted men and grand achievements, and while in some particulars we criticise it for what it is, we revere it for what has been accomplished within its walls.

"It is good for as many of the members as possible to occasionally meet in this manner, for, although we have common interest in the Institute and its work, our opportunities for acquaintance, or even for recognizing who are members, are limited. Some know each other by association in the Board of Managers or by co-operation in Institute committees and Sections. We exchange a few words at monthly meetings or at the lectures, or bow to one another in the library, and our many non-resident members are practically acquainted only as readers of the Franklin Institute Journal. There are few organizations whose membership numbers 2,500 which so seldom meet as a body, for research or study are best carried forward by individuals or groups of individuals.

"The old home is thrown open to-night and the various Sections have secured interesting exhibits for your instruction and entertainment. This Lecture Room is occupied for meetings of the Institute, of its Committees, and Sections for fully seventy-five nights in each year, and we provide two courses of popular free lectures at the hall of the Young Men's Christian Association, because of our limited facilities. In this room the Committee on Science and the Arts has for many years discussed the merits of a multitude of inventions, and by the bestowal of medals and awards has greatly advanced the importance of many of these, or by its refusal to approve has diverted effort from mistaken channels.

"On the floor above is our priceless library of 52,000 volumes, most of which are now secured against destruction in a fire-proof stack room. These volumes and 37,000 pamphlets are available every week-day in the year (holidays excepted).

"The third floor, at this season, is occupied five nights each week by 240 young men who come to study drawing, machine design and naval architecture.

"The management wishes you, as members and friends of the Institute, to appreciate that an earnest effort is made to use all our facilities to the best advantage, and it also desires you to know that its intentions are constantly hampered by a limited space and a restricted income.

"Here we have an association of men and women which for seventy-six years has been active in "the promotion and encouragement of manufactures and the mechanic and useful arts," and which has won and maintains a world-wide reputation; an organization which has rendered efficient and valuable service to City, State and Nation and to the World, yet has never received, as a gift, one dollar of public money. Some of the members may suggest that certain appropriations of public funds were made, and this is true. The city of Philadelphia, twenty-five years ago, appropriated $1,000 for the expenses of an expert commission to be nominated by the Institute, and with the approval of the Mayor, to report upon the future water-supply of Philadelphia, but none of this money came to the Institute, which rendered the city gratuitous service in selecting the commission. As early as 1843, the State appropriated money to equip stations for meteorological work, and this was done and the reports were made through the Franklin Institute, but, as further State aid was withheld, the work had to be abandoned. It was revived in 1887, and two appropriations of State funds for the same purpose were made, with which an efficient weather bureau was established, and ultimately turned over in working order to the United States Department of Agriculture. There was, however, no profit in this for the Institute, nor was any of the appropriation available for its general use.

"An appropriation made by Congress more than fifty years ago for conducting the investigation of boiler explosions was applied to defraying the expenses of the investigation, to which many months were devoted; but neither the investigators nor the Institute received any compensation.

"Tests of various forms of water-wheels; investigations into the strength of materials; into the suitability of building stones; into our system of weights and measures; into smoke abatement; into the shapes and proportions of screw threads, which finally resulted in the universal adoption of the Franklin Institute standard; and the studies of the earlier forms of dynamos and incandescent lamps, were carried on by the Institute without compensation, although in some cases the work was undertaken at the request of the municipal, State or the National Government.

"The Institute has been, and is now, supported mainly from the dues of its members, supplemented occasionally by profits from exhibitions, or from gifts, principally from members. It has not, nor never has had, an endowment to produce a yearly revenue sufficient to represent any considerable portion of the cost of its maintenance.

"The Institute has received valuable gifts of books, instruments and money, the latter amounting to but $71,000, which at present interest rates would cover about 15 per cent. of the annual expenses. More than one-half of this endowment is, however, under restrictions, and while the funds may be applied to the purchase of certain classes of books, to binding, or to cover the

expense of medals, the earnings of this portion of the permanent fund are not applicable for the maintenance of the Institute.

"We gratefully remember the aid rendered by the comparatively few who, when able to do so, have given substantial evidence of appreciating the work of the Institute, and it may be that some friends may bequeath liberal sums to the Institute, but we prefer such friends should aid it now and live to see the results achieved through their generosity.

"That we are in need of a new and more commodious building has been evident for years. Our lecture hall cannot accommodate the audiences which gather to listen to the excellent presentations which compose the Institute courses. Our library is stored in contracted quarters, and our reading-room gives small space for students. Our sections, schools, etc., have grown beyond the accommodations which we have to offer, and our location, through the changes in business centers, is less desirable than formerly.

"But the policy has been to show that every part of this venerated structure is thoroughly utilized, and that we are making the best of our limited facilities. We hope to crowd ourselves out of the old home into a new one, some time in the near future.

"Surely an organization which has done so much unselfish work, the value of which is recognized throughout the world; that has educated so many young men; that has given the public access to its really excellent library, all without profit or gain, is worthy of support, especially when the help desired is to be devoted solely to extending its work.

"We are ready to be judged by what has been accomplished, in asking whether it is to the credit of our city, State or nation that an institute which, if it could be transferred across the ocean, would be handsomely endowed and housed, should be restricted in its sphere of usefulness because of a limited income.

"You members of the Institute may well be proud to wear its badge, a symbol which is respected in every American and European technical society or library, an emblem of one of the earliest and long-continued efforts to show the true brotherhood of man in co-operative research and work to benefit his fellow-man.

"Is it your wish that the Franklin Institute should keep pace with modern invention and improvement; that its lecture courses shall be maintained at the high standard established; that its library receive all the new technical publications and that its worn volumes and periodicals be properly bound; that its sections and committees be unhampered by lack of funds to prosecute investigations; that its schools continue to aid young men who, employed during the day, seek a higher education at an institution which has, in this manner, helped thousands, many of whom are now noted specialists?

"If so, then there are ways open to you. Co-operation in raising the endowment fund for which Mr. Kuhn's committee is striving, and of which the interest only is to be used for maintenance, will assist in placing the Institute in position to do all that is desired. If unable to contribute or secure contributions to this endowment, you can present the advantages of the Institute and its work to acquaintances. There are surely in Philadelphia thrice as many men and women who would be members of the Institute if it were personally presented to them, and our 500 non-resident membership, scat-

tered throughout most of the States of this country, and some also in foreign lands, can be added to if the same method is followed.

"In the absence of assurance of prospective windfalls, the duty of maintaining the Institute remains with its members, and this duty is impressed upon each individually.

"Your Board of Directors desire that the Institute shall be self-supporting. In the four years during which it has been my privilege to preside over the Institute I have found the Board earnest and enthusiastic in its work, and also generous in meeting deficits by personal subscriptions. I am sure the members do not ask the latter from those chosen to administer the affairs of the Institute, and, as this has appeared an opportune occasion to invite attention to the necessity of every one co-operating, it has been taken advantage of in the hope that this imperfect presentation will stir the pride and encourage the interest of each member and friend of the Franklin Institute to relieve the organization from a forced economy which contracts its usefulness and limits the service it can render in 'the promotion and encouragement of manufactures and the mechanic and useful arts.'"

The contributions of the several Sections are enumerated below:

Specimens of viscose silk in skeins, (*a*) unbleached, (*b*) bleached, (*c*) dyed. Fabrics made from viscose silk with cotton warp, (*a*) unbleached, (*b*) bleached. Novelty fabrics (portières) made from viscose silk in colors, with cotton warp. Artificial horsehair made from viscose. Mackintosh cloth made from rubber-viscose dough.

(Exhibited by Prof. J. M. Matthews, Philadelphia Textile School.)

A collection of the rare earths and their salts, embracing compounds of lanthanum, praseodimium, neodimium, zirconium, thorium, etc., and of the newly-discovered elements samarium and gadolinium.

(Exhibited by Dr. Waldron Shapleigh, chemist to the Welsbach Light Company, Gloucester, N. J.)

A huge furnace section of carborundum, finely crystallized.

Specimens of artificial graphite (pseudomorphs) formed by the dissociation of carborundum (silicon carbide), preserving the crystalline structure of the carborundum.

(Exhibited by the Acheson Graphite Company, Niagara Falls, N. Y.)

Carbonless manganese (96·5 per cent. Mn) made by reduction of the monoxide by aluminum.

(Exhibited by the Carbonless Manganese Company, Philadelphia.)

A collection of specimens of hides tanned with formaldehyde.

(Exhibited by Dr. Chas. S. Dolley, Philadelphia.)

A collection of ferro-alloys, embracing ferro-nickel, ferro-tungsten, ferro-chrome and ferro-molybdenum, and of a new bearing-metal with 12 per cent. of lead.

(Exhibited by the Ajax Metal Company, Philadelphia.)

A collection of armor plate and other steel chips, showing the remarkable performance in speed of cutting and depth of cut achieved by the Taylor-White steel cutting tools.

(Exhibited by the Bethlehem Steel Company, South Bethlehem, Pa.)

Specimens of fire-proofed wood, and photographs of apparatus therefor.

(Exhibited by the U. S. Fire-proof Wood Company, Philadelphia.)

Moving picture machines (three movements); projecting microscope; projecting polariscope; projecting spectroscope.

(Exhibited by Williams, Brown & Earle, Philadelphia.)

Improved gas calorimeter (constant reading); improved gold assay balance distinctly sensitive to $\frac{1}{100}$ milligram (claimed to be the most sensitive balance manufactured in the United States); tintometer (Lovibond's) for recording colors and shades; X-ray tube with improved vacuum-regulating device, and device for preventing heating of platinum and blackening of inside of tube; Dewar bulbs and cylinders, plain and silvered, for liquid air; improved Spencer microscope; improved attachable mechanical stage for same.

(Exhibited by Mr. Simeon Trenner, agent for Eimer & Amend, New York, and the Spencer Lens Company, Buffalo, N. Y.)

Portable cable testing outfit; tripod d'Arsonval galvanometer; projection galvanometer; portable photometer; localization apparatus; specific gravity balance; Continental microscope, No. II; microscope for examining metals; Ryan electrometer; projection micro-polariscope; Sayen's self-regulating X-ray tube (awarded John Scott Medal by the Franklin Institute); Ayrton shunt box; Overshed testing set and generator, 500 and 1,000 volts, Queen & Co., Inc., American manufacturers; apparatus for determining sulphuretted hydrogen.

(Exhibitors, Messrs. Queen & Co., Philadelphia.)

Model of movable stairway, exhibited by Mr. James M. Dodge, Link-belt Engineering Company, Nicetown, Phila.

A large assortment of seamless cold-drawn steel tubes and cylinders, for air, steam, gas or fluids under pressure.

(Exhibited by Messrs. Janney & Steinmetz, Philadelphia.)

Electro-chord piano.

(Exhibited by Mr. George Breed, Philadelphia.)

Three sizes pneumatic chipping and caulking hammers, Nos. 1, 2 and 3; No. 8 pneumatic hand riveter for driving inch rivets; No. 7 pneumatic hand rammer, weight 20 pounds, No. 8 pneumatic hand rammer, weight 45 pounds, three styles rammer blocks; different styles chisels used with chipping and caulking hammers; rivets driven with pneumatic hammer, showing cross-section; section ¾-inch steel boiler plate, showing chips 3 feet long by ⅛ inch thick, made with No. 3 hammer at the rate of 1 foot per minute.

(Exhibited by the Philadelphia Pneumatic Tool Company.)

Automobile steam motor.

(Exhibited by Mr. Jas. T. Halsey, Philadelphia.)

Photographs.—Of these a large collection, principally the work of members of the Institute, was displayed about the walls of the Reading Room. The following exhibitors were represented: Wm. D. Anderson, Edward Brown, John Carbutt, Alfred Clegg, J. Logan Fitts, Spencer Fullerton, Richard Gilpin, A. M. Greene, Jr., Wm. O. Griggs, M.D., M. C. G. Grosholz, F. Gutekunst, Henry Howson, Messrs. Jennings & Sawyer, Werner Kaufmann, Frank J. Keeley, Thos. C. Martindale, Jr., Carl A. Oldach, J. W. Ridpath, Alfred Rigling, H. Ritter, Frank Roselle, Samuel Sartain, Alfred N. Seal, Thos. S. Stewart, Wm. H. Thorne, Messrs. Williams, Brown & Earle, U. C. Wanner.

W. H. W.

BOOK NOTICES.

American Telephone Practice. By Kempster B. Miller, M.E. Large 8vo, pp. x-458. New York: American Electrician Company. 1899.

The author of this work has succeeded in making a comprehensive treatise covering all phases of telephony in language free from mathematical abstrusities, so that it may be adapted to the comprehension of the average non-electrical reader in search of information. The book embraces an historical sketch of the development of telephony, in which the general principles of the art are elucidated, and a more or less elaborate exposition of the design and construction of commercial apparatus, and of the method of constructing, operating and maintaining them. W.

Municipal Public Works. An Elementary Manual of Municipal Engineering. By Ernest M'Cullough, C.E. Published by the author. Lewiston, Idaho. Second edition. 8vo, pp. 150. Paper cover. (Price, 50 cents.)

This work was originally prepared for the trustees of a California town, the intention of the author being to discuss from the engineer's standpoint, and in a thoroughly practical way, the numerous questions relating to municipal public works, with which such a body has to deal.

The several chapters treat respectively of streets, drainage and sewerage, water supply, street lighting and fire protection, plans and surveys, municipal ownership, and the city engineer. All these are treated of in a manner suited for the comprehension of the average town officer charged with the responsibility of acting on questions of town improvements. The author's opinion on the question of municipal ownership is adverse. W.

De Paris aux mines d'or de l'Australie occidentale. Par O. Chemin, Ingénieur en chef des Ponts et Chaussées, etc. Paris: Gauthier-Villars. Petit in-8, avec 111 photogravures, 9 cartes dans le texte et 2 planches. 1900. (9 francs.)

The author was charged by the Minister of Public Instruction with a mission to examine and report upon the gold mines of Western Australia, and after spending about a year in the examination of that region, he gives in the volume above entitled a summary of his observations. Inasmuch as the mining region covered by M. Chemin's itinerary is comparatively unknown, having been very little written about, his contribution to the history of the region should be of more than usual interest to those in search of such information. W.

Power Transmitted by Electricity and applied by the electric motor; including electric railway construction. By Philip Atkinson, A.M., Ph.D. Second revised edition. 8vo, pp. ix-241. New York: D. Van Nostrand Co.; London: Crosby, Lockwood & Son. 1899. (Price, $2.)

The second edition of the present work is issued under a new title, the first edition, which appeared in 1893, having been entitled "The Electric Transformation of Power." The work is written in plain, untechnical style, to adapt it to the comprehension of the non-mathematical reader, and from

the inspection that we have been able to give it, it appears to be well adapted for its intended class of readers. The revisions and additions made to this edition have brought the subject-matter up to date. W.

Standard Polyphase Apparatus and Systems. By Maurice A. Oudin, M.S., etc. 8vo, pp. 249. New York: D. Van Nostrand Co.; London: Sampson Low, Marston & Co., Ltd. 1899. (Price, $3.)

The author's purpose in this work has been to afford electrical engineers and those generally in charge of polyphase machinery a volume of information, in conveniently accessible form, bearing on the characteristics, uses and *modus operandi* of polyphase apparatus. The author appears to have done his work thoroughly well. W.

Franklin Institute.

[*Proceedings of the annual meeting held Wednesday, January 16, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 16, 1901.

President JOHN BIRKINBINE in the chair.

Present, 79 members and visitors.

Additions to membership since last month, 10.

The President made some informal comments on the facts contained in the Annual Report of the Board of Managers, printed copies of which were placed in the hands of the members. The Report with accompanying Appendices was accepted.

Dr. Henry Leffmann, by special invitation, presented a communication on "The Applications of Photography to Police and Sanitary Administration." The speaker received the thanks of the meeting, and the communication was referred to the Committee on Publications.

Mr. Arthur F. Bardwell, C.E., of New York, gave a description of the mechanical construction, operative features and capabilities of the Bardwell votometer, illustrating the subject by the exhibition of one of the machines.

The Secretary made a brief allusion to an interesting series of specimens illustrating the utilization of the wastes from the galvanizing of iron. These embraced the so-called sal-ammoniac skimmings, surface and heavy dross, the various grades of refined spelter recovered, "aluminized" zinc used in the refining process, aluminum-zinc alloys, electrolytic zinc, and samples of the final residuum, known as the "bottoms," which is subjected to distillation. The samples were exhibited by Mr. Joseph Richards.

The tellers of the annual election held this day, between the hours of 4 to 8 P.M., reported that the nominees for officers, managers and committeemen placed in nomination at the stated meeting of December 19, 1900, had received all the votes cast. They were thereupon declared elected. The tellers received a vote of thanks.

Adjourned.

WM. H. WAHL, *Secretary.*

APPENDIX.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE FOR THE YEAR 1900.

To the Members of the Institute.

GENTLEMEN:—The Board of Managers is able to chronicle another year of successful effort to carry forward the objects for which the Franklin Institute was organized and can repeat its statements of a year ago, that every section and every committee has been active, that the membership has increased and that substantial progress has been made. But it must also again call attention to the fact that the revenues of the Institute are insufficient to properly prosecute the work desired and that which may properly be expected of the Institute.

Much of the time of the Board, which could otherwise be devoted to expanding the field of its usefulness, is of necessity given to discussing means of making a limited exchequer cover the varied requirements of the library, the Journal, sections, meetings, schools, etc.

While economy is a virtue not to be deprecated, our necessities have required parsimony in some directions. The Library Committee have to reduce expenditures to the extent of denying to the members many publications which should be added to our valuable collections; sections are restricted in their work by the inability of the Board to supply funds for laudable investigations, and the Institute is thus seriously handicapped in every direction. Your Board has carefully considered each item of expenditure and is satisfied that none of the Institute funds are misapplied or wasted. The financial statement appended indicates the sources of income and exhibits the fact that the endowment funds are far from sufficient to materially aid in maintaining the usefulness of the organization.

It is essential that we keep pace with other institutions, following in the path broken by the Institute, but which have handsome endowments. And it is against such odds that we must contend without similar resources.

To be in the van with a technical library demands large expenditures for rapidly augmenting publications.

To maintain interest in the Institute and sectional meeting necessitates liberality in preparing data or exhibits.

These facts, taken in connection with the decline of interest rates, make demands beyond the available income.

Hence the Board appeals to its members to co-operate in relieving the Institute by augmenting its endowment or increasing its income.

The permanent investments and the value of our building site are valuable assets—but they are insufficient to maintain our activity as every loyal member desires it to be maintained.

This statement is presented to encourage the membership at large to assist in placing the Institute in a better financial position.

The Board does not desire to have this presentation indicate discouragement; on the contrary, the reports appended, and which are briefly summarized below, give proper cause for congratulation.

The Institute, with its building, its moderate endowment and its library, is far from being in financial difficulties.

But we cannot afford to entail our resources for temporary revenue.

To properly maintain the work of the Institute will require a larger annual income, and the statements which appear in the various reports appended will indicate that with a small outlay important results are accomplished.

These reports show that in the past year the Committee of Science and Arts considered 100 cases, and thirty-three medals or certificates of merit granted.

That two courses—12 lectures in all—were held in the Y.M.C.A. Hall.

That three night schools, viz.: a school of Drawing, of Naval Architecture, and Machine Design, were maintained.

That ten stated meetings of the Institute were held and one reception.

That there were thirty-five meetings of sections, at which a number of important papers were read, or discussions had; that 1,243 bound and 638 unbound books and more than 1,500 pamphlets, maps and charts, or 3,409 numbers were added to the library; that the membership, principally in the non-resident list, increased by nearly 200 accessions, and that a larger edition of the Journal was published than ever before; and yet, to cover this entire field of work, maintain the building in good repair, heat it, light it, etc., there was available a total of but $19,557.27.

With your co-operation in the seconding the efforts of your Committee on Endowment and in securing substantial additions to our list of resident members, the continual embarrassments of your Board, arising from insufficiency of revenue, could readily be done away with.

Appended are the data relating to the operations of the various branches of the Institute.

By order of the Board.

JOHN BIRKINBINE,
President.

PHILADELPHIA, January 9, 1901.

REPORT OF THE COMMITTEE ON ELECTION AND RESIGNATION OF MEMBERS, 1900.

Members at the close of 1899	2,151	
Number of new members elected who have paid their dues in 1900	211	
		2,362
Lost by death, resignation and non-payment of dues		75
Total membership at the end of 1900		2,287

FINANCIAL STATEMENT FOR THE YEAR 1900.

Balance on hand January 1, 1900	$107 81
Receipts	20,657 27
Payments	19,713 22
Balance	$1,051 86

ANNUAL REPORT OF THE COMMITTEE ON INSTRUCTION, 1900.

To the Board of Managers.

GENTLEMEN:—Your Committee on Instruction has to report, in reference to the popular scientific lectures which for several years have become something of an established feature, that the joint arrangement for co-operation with the Young Men's Christian Association was continued during the past year, and that, as heretofore, the outcome has proved to be notably satisfactory. The Committee has been able, as heretofore, to secure the gratuitous services of its lecturers, and the general interest and excellence of the courses has been attested by the unusually large attendance.

The Committee herewith expresses its great obligations to its lecturers for their services.

The school work during the past year has been unusually active. What is practically a new school has been started with flattering prospects of success, and all have shown an encouraging increase in the number of pupils in attendance.

There are now in active operation three night schools, the Drawing School, the School of Naval Architecture and the School of Machine Design. The last-named is an outgrowth of the School of Elementary Mathematics, founded two years ago, and, although just inaugurated, has a considerable body of pupils, and its prospects are such as to give the Committee much satisfaction.

The School of Naval Architecture, founded two years ago, also, has enjoyed a substantial growth, and the Committee hopes soon to be able to arrange for the widening of its scope to embrace the allied subject of Marine Engineering.

The Drawing School continues to maintain its reputation for thorough instruction, and has shared in the general prosperity of the schools.

The following data of attendance are presented for comparison:

	1899.	1900.
Drawing School	231	298
School of Naval Architecture	36	61
School of Machine Design	30	61

The Committee, in conclusion, is pleased to report that all those connected with the schools, directors and assistants, have exhibited the utmost zeal in promoting their interests.

Respectfully,

WM. H. WAHL,
Chairman Committee on Instruction.

January 1, 1901.

ANNUAL REPORT OF THE COMMITTEE ON THE LIBRARY FOR THE YEAR 1900.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Committee on the Library respectfully reports the following summary of the operations of the Library during the year 1900:

	Bd. Vols.	Unbd. Vols.	Pphs.	Chts.	Designs.
Additions	1,243	638	1,498	20	10
Total additions for the year					3,409

A decrease of 177 from 1899, but an increase of 572 over 1898, and 483 over 1897.

Total number of volumes, January 1, 1901	52,229
Total number of pamphlets, January 1, 1901	37,043

The Library also contains 2,827 maps and charts, 652 designs and drawings, 1,222 photographs, 191 newspaper clippings, 30 manuscripts.

Exchanges.—Four hundred and ninety-seven societies and publications were on the exchange list of the journal during the year 1900, an increase of ten over 1899.

The Library is consulted by a daily average of about 150 visitors, two-thirds of them in search of patents.

It is evident that the Library, with its remarkable collection of over 90,000 books, pamphlets, maps and drawings and its large daily attendance, is the most important feature of the Institute, useful as are the general and sectional meetings, the lectures, the schools and the Journal. The meetings, especially the section meetings, produce original material, the Journal brings it in a perthanent form before the world, the schools teach a certain number of students; but the Library, a vast repository of all kinds of applied science, is consulted by thousands, and is used by great numbers in elaborating new material. The Journal itself, which is to the outside world the flower—yet more, the fair and substantial fruit of our whole plant—has perhaps its greatest usefulness in bringing directly, or indirectly, acquisitions and support to the Library. There is every reason, then, for making the utmost effort to supply the urgent needs of the Library.

The Library is still sorely lacking in space, as intimated already last year. Especially, the extremely valuable collection of over 37,000 pamphlets lies practically useless, without shelving, in the third story of the part of our building that is not fire-proof; and proper accommodation for the invaluable collection of drawings and charts is still lacking.

We would strongly urge the advantage of making room for the pamphlets by taking the Seventh Street end of the drawing school, above the present book-stack. The space so taken would be ample for the pamphlets, and could be made practically fire-proof by a brick wall between it and the rest of the school, and by a corrugated iron ceiling below the slate roof above. The fire-proof character of the main book-stack would not be diminished, for the new room would be entered by way of the school stairs, and there would be no opening to it from the stack. The expense has been roughly estimated at only $600. The alternative is to take one of the rooms on the lower floor, near the front door, but the cost would quickly overbalance the expense of the other more convenient arrangement.

The Library, with its numerous constantly arriving accessions to be thoroughly catalogued and arranged, and the large number of visitors to be waited upon, is sadly in need of better means for more complete service in other matters of pressing importance. For instance, if the Librarian had one more assistant, much time could with great advantage be occupied in following up

the acquisition of a vast number of municipal and governmental annual or serial publications of great engineering value, and also innumerable trade catalogues, that would be of great use if systematically arranged. Such publications could be obtained gratuitously, because it is clearly to the interest of those who issue them to have them placed where they would be properly cared for and made readily accessible to the public. But it is necessary to look constantly with watchful eye for their appearance, and occasionally to inform a new official or a new manufacturer of our desire for the publications, and there is, besides, the attention required for the cataloguing and convenient systematic arrangement. The present service of the Library is too short-handed to attend properly to this very important branch of our work. Setting the pamphlets in proper order, when new quarters are provided, will also require a great deal of unusual labor.

The binding is still so far in arrears, a liberal appropriation for the purpose is earnestly desired, in order that good progress may be made towards a satisfactory condition of the Library.

The main addition of books has been, as usual, from special gifts, and next from the volumes of serials received in exchange for the Journal.

The Moore Fund, ordinarily yielding about $750 a year, has, unfortunately, the past year, enabled the purchase of but few books. The Memorial Library Fund, about $50 a year, has supplied a better number of books than the preceding year. The Lea Fund, about $150 a year, has now fairly begun to bring in new books. The James T. Morris Fund of $2,000 has not yielded any income for the purchase of books.

The zeal and harmony of the Library Committee continue unabated, and it is believed that benefit will result from its meetings and earnest discussions, even if the temporary condition of the fund investments should occasionally make it impossible to order books to be purchased.

BENJ. SMITH LYMAN,
Chairman of the Library Committee.

PHILADELPHIA, January 7, 1901.

ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1900.

GENTLEMEN:—The following summary of the work of the Committee on Science and the Arts for the year 1900 is respectfully submitted, showing that the large number of subjects presented for its consideration have received the usual careful attention expected, and have been passed upon impartially in accord with their merits. An unusual number of especially meritorious inventions have come to the Committee during the past year, due mainly to the references made of such subjects by the Board of Judges of the late National Export Exposition, in whose judgment such inventions were deserving of further recognition by the Franklin Institute, nearly all of which cases have been finally acted upon.

Very respectfully,
H. R. HEVL,
Chairman Committee on Science and the Arts.

PHILADELPHIA, January 2, 1901.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 1, 1901.

STATISTICS OF THE OPERATIONS OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR 1900.

Cases pending December 31, 1899	35		
Applications received in 1900	27		
Cases referred by Institute	2		
Investigations ordered by Committee	5		
Investigations referred by Jury of Awards, National Export Exposition	31		
		65	
			100
Cases considered in 1900	58		
Cases finished in 1900	52		
Cases pending December 31, 1900	48		
			100
Reports pending same date			6
Awards of the Elliott Cresson Medal			6
Recommendations of the award of the John Scott Legacy Premium and Medal			12
Awards of Edward Longstreth medals of merit			12
Awards of certificates of merit			3
Reports made advisory			8
Cases withdrawn			2
Cases dismissed			8
Reports without awards			4
Protests			1
Cases pending December 31, 1900			48

ANNUAL REPORT OF THE COMMITTEE ON MEETINGS, 1900.

To the President and Members of the Institute:

The Committee on Meetings has arranged the program for the ten stated meetings of the Institute, with the Secretary's co-operation, and from the general interest exhibited by the members in these monthly gatherings the Committee may hope that its efforts to provide attractive material have been successful.

These arrangements have resulted in the presentation of twenty-three papers and miscellaneous communications, a number of which have found their way into publication, and others have been referred to the Committee on Science and the Arts.

The Committee has continued the publication of the Monthly Bulletin, which, although involving considerable cost, it is believed to be good policy to continue as heretofore. It should be said, in conclusion, that the growing activities of the Institute in the various sections are steadily making it more difficult for the Committee to maintain the greatest possible interest in the monthly meetings, but this circumstance the Committee believes to be rather

a subject for congratulation than the reverse, since it is the evidence of greater individual activity on the part of members in promoting the objects for which the Institute was organized.

Respectfully,

WASHINGTON JONES,
Chairman Committee on Meetings.

January 1, 1901.

ANNUAL REPORT OF THE CHEMICAL SECTION FOR THE YEAR ENDING DECEMBER 31, 1900.

The Committee on Sectional Arrangements:

The Chemical Section has held eight meetings during the past year, at which the following communications were presented and discussed:

Prof. S. F. Peckham. "What is Parianite?"

Prof. Edward L. Nichols, Cornell University. "Investigation of the Acetylene Flame."

Mr. B. H. Morrison. "Chemistry of Paper."

Dr. S. P. Sharples, Boston. "The Utilization of Animal Wastes."

Dr. S. P. Sadtler. "A Review of the Subject of Mineral Tanning."

Dr. Joseph W. Richards. "Report on the Aluminium Industry as shown at the Paris Exposition."

Dr. Richards. "The Utilization of Blast Furnace Gases in Gas Engines."

Dr. Henry Leffmann. "Methods of Micro-Chemical Analysis."

Mr. Charles J. Reed. "Electro-Chemical Action" (Joint Meeting with Electrical Section).

Several of these communications were published, with discussion thereon, in the Journal.

In the early part of the year, the Photographic and Microscopic Branch of the Section was, on the petition of its members, allowed to sever its connection with the Section and reorganize as an independent Section.

The meetings were as a rule well attended and the membership and general interest in the Section's work has been maintained.

By order of the Section.

W. J. WILLIAMS,
President.

W. E. RIDENOUR,
Secretary.

ANNUAL REPORT OF THE ELECTRICAL SECTION FOR THE YEAR 1900.

The Committee on Sectional Arrangements:

The Electrical Section has fully maintained its activity during the past year. Nine meetings were held, all of which were well attended, and of the papers presented, several were of considerable importance, as an inspection of the Journal in which they appear will testify.

Following is a list of authors and titles of communications presented during 1900:

Prof. John Price Jackson, State College, Pa. "Electrical Machinery in Coal Mining."

Prof. W. S. Franklin, Lehigh University. "Mechanical Conceptions of Electricity."

(Discussion) "Incandescent Lamps."

Mr. Adam Bosch, Newark, N. J. "Development of the Fire-Alarm Telegraph."

Mr. Chas. F. Scott, Westinghouse Electric and Manufacturing Company. "Modern Central Station Practice."

Mr. J. Franklin Stevens, Philadelphia. "Electrical Instruments."

Mr. C. H. Bedell, Philadelphia. "An Electrical Revolution Indicator."

Mr. Bedell. "The Pfatischer Electrical Steering Gear."

(Discussion) "The Electrical Distribution of Power in Workshops." (Joint meeting with the Mechanical and Engineering Section.)

Mr. Chas. J. Reed, Philadelphia. "Electro-Chemical Action." (Joint session with the Chemical Section.)

The outlook for the continued activity of the Electrical Section is most favorable.

Respectfully submitted,

W. S. FRANKLIN,
President.
RICHARD L. BINDER,
Secretary.

ANNUAL REPORT OF MINING AND METALLURGICAL SECTION FOR THE YEAR 1900.

The proceedings of the Section have been conducted by the following officers:

President, Mr. Joseph Richards.

Vice-Presidents, Mr. A. E. Outerbridge, Dr. David Tuttle.

Secretary, Mr. G. H. Clamer.

Conservator, Dr. Wm. H. Wahl.

Membership.—The total membership at the present date shows an increase of ten over the year 1899.

Meetings.—The Section held ten meetings during the year.

Work of Section.—The papers which were presented at the various meetings were all of decided interest, as was also the discussion of Mr. Paul Kreuzpointner's paper, "Riddles Wrought in Iron and Steel." This discussion was made the subject of several meetings, and has added much to the valuable work of the Section.

The following papers were presented:

Prof. F. Lynwood Garrison. "Lead and Zinc Mines of Southwestern Missouri."

Dr. David T. Day. "Modern Uses of Fuller's Earth."

Mr. Wm. Griffith. "Flushing of Culm into Anthracite Coal Mines."

Prof. John Gifford. "Forestry in Europe and America."

Mr. Paul Kreuzpointner, Mr. A. E. Outerbridge, Mr. Wm. R. Webster. (Discussion of Mr. Kreuzpointner's Paper) "Riddles Wrought in Iron and Steel."

Mr. Robert Job. "Some Causes of Excessive Heating in Bearing Metals."

Mr. Joseph A. Steinmetz. "Practical Application of Aluminum."

Prof. F. Lynwood Garrison. "Mines and Minerals of China."

Mr. Chas. Morris. "Subterranean Waters."

JOSEPH RICHARDS,
President.

G. H. CLAMER,
Secretary.

PHILADELPHIA, January, 9, 1901.

ANNUAL REPORT OF THE MECHANICAL AND ENGINEERING SECTION FOR 1900.

Committee on Sectional Arrangements:

During the past year the Mechanical and Engineering Section held seven meetings, several of which were largely attended. The policy has been adhered to in the main, of devoting the meetings to the discussion of subjects of live engineering and mechanical interest.

The following subjects were discussed:

"Portable Machine Tools."

"Power Transmission by Belting, Ropes and Chains."

"Expanded Metal; with Especial Reference to Reinforced Concrete Construction" (paper by James S. Merritt).

"The Economical Operation and Maintenance of Steam Boilers, and "Electric Transmission of Power in Workshops."

The last-named theme was discussed in joint session with the Electrical Section.

Several of these subjects found place in the Journal.

The general interest of the members in the work of the Section continues unabated, and the officers are pleased to be able to report a favorable outlook for the coming year.

Respectfully submitted,

JOHN F. ROWLAND, JR.,
President.

DANIEL EPPELSHEIMER, JR.,
Secretary.

PHILADELPHIA, January 10, 1901.

ANNUAL REPORT OF THE SECTION OF PHOTOGRAPHY AND MICROSCOPY FOR THE YEAR 1900.

The following is a summary of the work of the Section during 1900, including the period in which the Section was carried on as a branch of the Chemical Section:

January 2d.—A new method of entitling lantern slides. John G. Baker. "Micro-Photography and Photo-Micrography," with illustrations by several members.

February 6th.—"The Applications of Photography and Microscopy to Medico-Legal Work." At this meeting the Section had the honor of com-

munications from two experts. Dr. W. M. L. Coplin gave an illustrated lecture, dealing principally with the recognition of blood stains, and Dr. A. W. Goodspeed exhibited a number of slides relating to X-ray work and also showed some pictures made with radiant substances.

March 6th.—"Apparatus for Testing the Speed of Camera Shutters." John G. Baker. "Remarks on the Chemistry of Development." Dr. Henry Leffmann.

April 3d.—"Development of Lantern Slides." S. Ashton Hand. Mr. Hand's collection of slides was a striking example of the value of a combination of science and technic in securing true and artistic results in photography.

"Picture-Making in the Dark." Dr. M. I. Wilbert. Dr. Wilbert exhibited a large number of slides made from negatives taken without any exposure to light, and also showed some pictures made from very old plates.

May 3d.—"Notes on Sodium Gold Chloride." Lyman F. Kebler. This communication pointed out the difference in net weight in the different brands of the article in the market.

"Remarks on the Subject of Picture-Making in the Dark." Dr. Henry Leffmann.

October 4th.—"Photographic Sophistications." John Bartlett. This paper was of novel character and aroused much interest.

November 1st.—"Notes on the History and Applications of Motion Pictures." Communications were presented by several members. Some very old motion slides were shown. Mr. Ives exhibited the "kicking donkey" adapted from Muybridge's picture. Mr. Heyl showed some slides which had been used in 1870 at an exhibition under the auspices of the Institute. These slides were used to exhibit motion effects.

December 6th.—"The Microscopic Structure of the Rocks of the Philadelphia District." Theo. D. Rand. This was largely illustrated and was an interesting and valuable contribution to local petrology.

Respectfully submitted,

HENRY LEFFMANN,
President.

F. M. SAWYER,
Secretary.

PHILADELPHIA, January 3, 1901.

ANNUAL REPORT OF THE PHYSICAL SECTION FOR THE YEAR 1900.

The Committee on Sectional Arrangements:

The Physical Section labors under the disadvantage, as compared with the other Sections of the Institute, of having a much smaller membership from which to draw for material for its meetings, being compelled on this account to depend more than the others upon contributions from non-members. This will, in a large measure, explain the occasional omission of one of its meetings.

The following communications were presented during the year just past:

Prof. Jesse Pawling, Jr., "Trilinear Coördinates as Applied to a Particular Problem."

Professor Pawling, "On Magnetic Curves."

Dr. G. B. M. Zerr, "On Aberration."

Prof. E. L. Nichols, Ithaca, N. Y., "The Acetylene Flame."

Mr. H. M. Watts, "On the Past History and Present Prospects of State Weather Services."

Dr. M. G. Lloyd, "On Thermo-Magnetic Effects."

The Physical Section, in conjunction with the Photographic and Microscopic Section, prepared and issued a joint bulletin giving instructions to its own and other observers of the total eclipse of May 28, 1900. Also, steps were taken looking to the appointment of a special committee to confer with the several scientific and educational institutions of the State, with the view of establishing a Weather Service on the lines suggested by the Maryland State Weather Service.

To increase the interest of the general membership of the Institute in the Section, it was decided to endeavor to devote more attention, if practicable, to the subjects usually included under the name of Terrestrial Physics. Also, the name of the Section was changed, by authority of the Board of Managers, to "The Physical Section" of the Franklin Institute.

Respectfully submitted,

A. E. KENNELLY,
President.

EDW. A. PARTRIDGE,
Secretary.

PHILADELPHIA, January 1, 1901.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, January 2, 1901.*]

MR. H. R. HEVL in the chair.

The following reports were adopted:

(No. 1992.) *System of Oil Heating and Incandescent Lighting.* Arthur Kitson, Philadelphia. Reserved for publication in full.

(No. 2124.) *Forged Steel Car and Locomotive Wheel.* Facer Forged Car and Locomotive Wheel Company, Philadelphia.

ABSTRACT.—This invention is the subject of letters-patent of the United States, No. 564,603, July 28, 1896, granted to applicant.

From an examination of the means described for producing this wheel, it appears that the arrangement of the top die is the same as that usually employed in the manufacture of tires. The difference between this and existing methods consists in the wheel being held in a V-shaped die in the former process, whereas the tires are held on the horn of the anvil in the latter. The sub-committee examined the subject from the standpoint (1) of novelty of the method; (2) excellence of workmanship; and (3) quality of product. As the result, the conclusion is reached that the applicant has not demonstrated that a marketable wheel can be made by the process, and that, in the absence of such proof, it was not considered necessary to enter into the consideration of the question of novelty. [*Sub-Committee.*—Thos. P. Conard, Chairman; H. V. Wille, J. Y. McConnell, A. E. Outerbridge, Jr., A. A. Stevenson, W. B. Riegner.]

(No. 2145.) *Method of Compressing Air by Means of Water.*

(No. 2146.) *Method of Raising Water by Compressed Air.*

ABSTRACT.—These inventions are the subject of U. S. letters-patent No. 199,819, January 29, 1878, and No. 233,499, October 19, 1880, respectively, granted to applicant, J. P. Frizell, Boston, Mass.

The first relates to a method of compressing air by means of the entrainment of air in minute bubbles by a stream of water. The water is carried vertically downwards within a pipe and the entrained air is liberated at any desired depth in a horizontal passage, the pressure corresponding to the height of the water column.

The investigating committee finds this principle of operation to be identical with that used in the apparatus known as the "trompe," an ancient device used in the Catalan forge. The investigators, moreover, consider the plan of applicant, of liberating the air in a horizontal passage, to be rather a step backwards. The method of Taylor (exhibited in the plant of the Dominion Cotton Mills, Magog, Canada), of liberating the air in a box, corresponds more closely to the form of the old trompe and, in their judgment, is simpler.

The second invention consists in a method for the aëration of a water column by the introduction of air in minute bubbles, thus reducing the specific gravity of the mixed fluids in the pipe, below that of the surrounding water. The mixed air and water consequently will rise to a considerable height above the water level. In the procedure known as the "Pohle Air Lift" (which is referred to by applicant as a substantial appropriation of his invention) the air is introduced in large volumes into a column of water, thus differing from the procedure of applicant. Furthermore, the Pohle method involves, not only the mixture of air and water and the utilization of the elasticity of the air which expands as the mixed fluid approaches the discharge outlet—which operations are embodied in the plan of applicant—but also adds the use of the inertia of the injected air as the pipe introducing the air into the water column is turned upwards in the direction of the stream, whereas in applicant's apparatus the air is introduced in a direction at right angles to the stream.

In the committee's opinion, all the principles involved in applicant's as well as Pohle's inventions are not new, being applied more or less completely in numerous forms of the devices known as ejectors. The conclusion is reached that applicant has not made any marked step in advance in his several inventions. [*Sub-Committee.*—A. Falkenau, Chairman; S. Howard Rippley, Arthur M. Greene, Jr., Wm. Copeland Furber, John E. Codman.]

SECTIONS.

(*Abstracts of Proceedings.*)

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, January 3, 1901. Dr. Henry Leffmann in the chair. Present, 32 members and visitors.

The annual election for officers resulted as follows: President, Dr. Charles

F. Himes; Vice-Presidents, F. E. Ives, John G. Baker; Secretary, Frank M. Sawyer; Conservator, Dr. Wahl.

The communication of the evening was the address of Dr. Leffmann, the retiring President, who spoke on "The Applications of Photography to Police and Sanitary Administration." The speaker's remarks were freely illustrated by means of lantern slides, which served to demonstrate very strikingly the great importance of the photographic art in the numerous varied fields covered by this work. The paper is reserved for publication.

F. M. SAWYER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, January 9, 1901. Mr. Joseph Richards, President, in the chair. Present, 18 members and visitors.

The annual election for officers resulted in the choice of the following: For President, Prof. F. L. Garrison; Vice-Presidents, James Christie, Joseph Richards; Secretary, G. H. Clamer; Conservator, Dr. Wahl.

The retiring President conducted his successor to the chair.

The paper of the evening was the address of the retiring President, Mr. Joseph Richards, who chose as his subject, "The Utilization of the Wastes from the White Metals." Only one branch of this interesting theme was considered at this meeting, namely, the Utilization of Galvanizers' Wastes.

The speaker illustrated the subject by means of an instructive collection of specimens of the various kinds of those wastes which were commercially utilized, and of the several qualities of refined metal obtained by various processes employed. Referred for publication.

The thanks of the meeting were voted to the retiring officer. By special request, the subject will be continued at the next stated meeting.

G. H. CLAMER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, January 10th. Mr. John F. Rowland, Jr., in the chair.

The evening was devoted to the presentation of an address on "Wear and Tear on Steam Boilers" by the retiring President, Mr. Rowland. The subject was afterwards discussed.

The annual election of officers was deferred until the next stated meeting.

DANIEL EPPELSHEIMER, JR.,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, January 17th. Vice-President Joseph Richards in the chair. Present, 23 members and visitors.

The following officers were elected to serve for the current year, viz.: President, Morris E. Leeds; Vice-Presidents, Joseph Richards, Geo. T. Eyanson; Secretary, Richard T. Binder.

There were presented two communications, both of which were freely discussed, viz.: "A New Departure in Constant-potential Arc Lamps," by Thomas Spencer, and "Three-phase Electric Traction in Europe," by Mr. Carl Hering.

RICHARD T. BINDER,
Secretary.